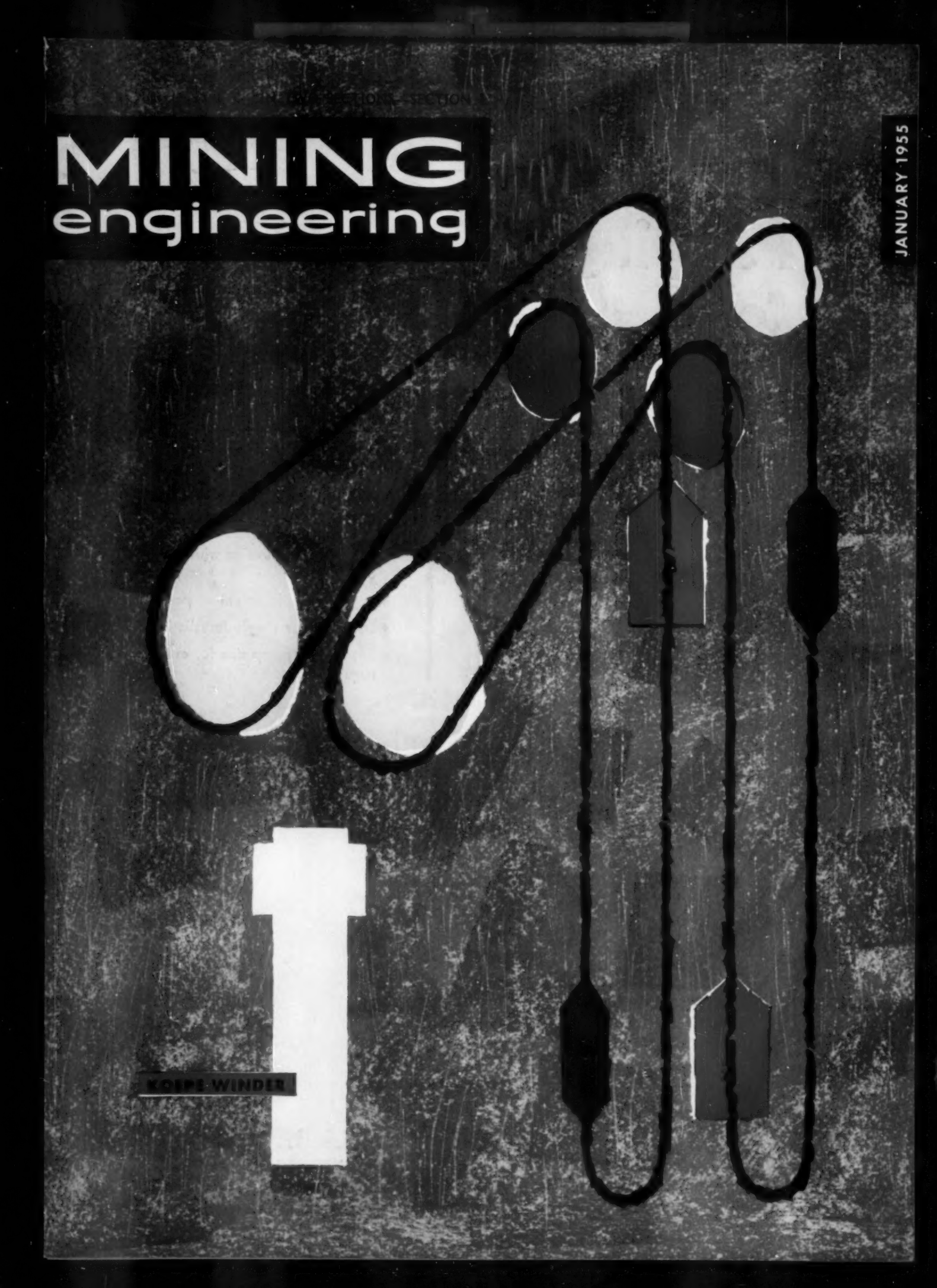
MINING engineering

JANUARY 1955



Lower Pumping Costs

IN HEAVY MEDIA SERVICE

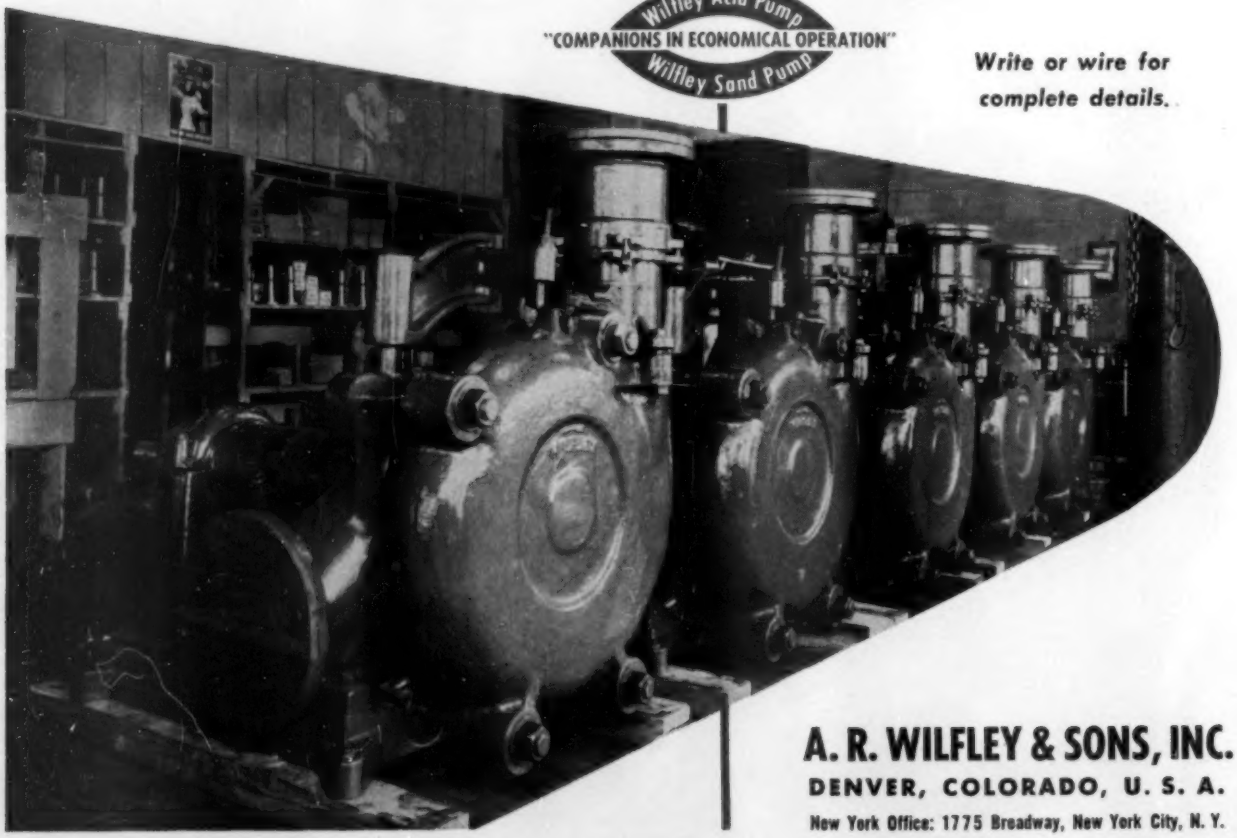
WILFLEY PUMPS

These Wilfley 8 inch Model "K" Sand Pumps are specifically designed for rugged, heavy duty service in a new coal preparation plant. These dependable, highly efficient pumps deliver continuous, trouble-free performance at low cost without media loss, leakage or dilution.

- Individual engineering on every application
- Cost-saving efficiency
- Reduced power and maintenance costs
- Continuous operation without attention
- Minimum replacement of parts
- Designed for simple installation
- Economical pump size for every requirement

Wilfley Acid Pump
"COMPANIONS IN ECONOMICAL OPERATION"
Wilfley Sand Pump

Write or wire for complete details.



A. R. WILFLEY & SONS, INC.
DENVER, COLORADO, U. S. A.
New York Office: 1775 Broadway, New York City, N. Y.

MINING engineering

VOL. 7 NO. 1 JANUARY 1955

In Two Sections—Section I (Index is Section II)

ALVIN S. COHAN
Manager of Publications
CHARLES M. COOLEY
Editor

• • •

RIXFORD A. BEALS
Associate Editor

M. A. MATZKIN
News Editor

SCOTT CONKLING M. E. SHERMAN
Assistant Editors

GRACE PUGSLEY, Production Manager;
W. J. SEWING, Asst. Prod. Mgr.

• • •

TECHNICAL PUBLICATIONS COMMITTEE
ROBERT H. ABORN.....Chairman
E. J. KENNEDY, JR.....Secretary

DIVISIONAL PUBLICATIONS COMMITTEE CHAIRMEN
H. C. WEED.....Mining
H. R. GAULT.....Geology
DART WANTLAND.....Geophysics
H. R. SPEDDEN.....Beneficiation
CARROLL F. HARDY.....Coal
R. W. SMITH.....Indus. Minerals
GEORGE B. CLARK.....Education
H. A. FRANKE.....Mineral Economics

• • •

WARREN V. SMITH
Eastern Advertising Manager

BOB WILSON
Mid-Western Advertising Manager
84 E. Randolph St., Chicago

McDONALD-THOMPSON
Western Advertising Representatives
625 Market St.
San Francisco 4, Calif.

• • •

The AIME publishes { Mining Engineering / Journal of Metals / Journal of Petroleum Technology }

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $10 foreign; $6 for AIME members, or $4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies $.75; single copies foreign $1.00, special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publication.

Copyright 1955 by the American Institute of Mining and Metallurgical Engineers, Inc.

Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC.

COVER

Koepe Winder or call it Friction Drive Hoist—the style of hoisting installation highlighted by artist Herb McClure seems destined for a major role in moving rock up and men and materials underground at U. S. mines. For full-dress treatment of friction drive hoisting, including details of two U. S. installations, formulas and design data, and a proposed safety code, turn to the article starting on page 25.

FEATURES

Personnel Service	2	Drift	23
Manufacturers News	8	AIME News	73
Reporter	13	Personals	87
Mining News	15	Professional Services	94
Trends	20	Coming Events	96

Advertisers Index 96

ARTICLES

Friction Drive Mine Hoists—
Recent Installations and Design Considerations
E. P. Pfleider, E. G. Malmlow, and F. Landau 25

TRANSACTIONS

Hydrothermal Alteration at the Climax Molybdenite Deposit
John W Vanderwilt and Robert U. King 41

Chuquicamata Develops Better Method to Evaluate Core Drill Sludge Samples
Glenn C. Waterman 54

Mining Hydrology Problems in the Birmingham Red Iron Ore District
Thomas A. Simpson 62

Quartz Flotation with Anionic Collectors
A. M. Gaudin and D. W. Fuerstenau 66

—Personnel Service—

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Geologist, 28, married, family, now employed. Five years experience including shaft and tunnel construction, surveying, drilling programs, geologic investigations for engineering projects, ground water development. Thorough knowledge of seismic and resistivity methods and their application to ground water and engineering problems. Excellent references. M-112.

(Continued on page 4)

DETECT URANIUM DEPOSITS
100 TIMES EASIER!

WITH THE PRECISION "SPECIAL SCINTILLATOR"®

DEALERS WANTED

Here is the ideal field instrument for Uranium prospecting. It's ultra-sensitive, low in cost, lightweight and small in size.

The model 117 "Special Scintillator" is made by Precision Radiation Instruments, Inc., manufacturers of the famous Model 111 "Scintillator."

Contact your nearest dealer or write direct for free complete catalog on instruments for detecting Uranium and other metals.

ONLY $299.50

PRECISION RADIATION INSTRUMENTS, INC.
2235 ME S. La Brea, Los Angeles 16, Calif.
Please send Free Catalog.
Name
Address
City Zone State
WORLD'S LARGEST MANUFACTURERS OF PORTABLE RADIATION INSTRUMENTS

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG.
CHAMBER OF MINES CHAIR OF MINING ENGINEERING

Applications are invited for appointment to the post of Professor in Mining Engineering who will be head of the Department of Mining.

The substantive salary attached to the post will be as arranged between the successful applicant and the University, but will not be less than £3,000 per annum. In addition, a married man will receive cost of living allowance at such rate as may be authorized from time to time, the present rate being £234 per annum.

Membership of the University Institutions Provident Fund is compulsory and involves a contribution of 7% of the pensionable salary, the government and the university together contributing an equal amount.

The pensionable salary is at present £1,600 per annum. Membership of the University's Staff Medical Aid Fund is also compulsory in the case of an officer who is eligible for such membership, and contribution will be in accordance with the rules of the fund.

The professor will be called upon as part of his duties to serve as a Consultant to the Transvaal and Orange Free State Chamber of Mines. He will not, except under special circumstances, be granted permission to engage in private consultative work.

Duties are to be assumed on the 1st July, 1955, or as soon as possible thereafter. Applicants are advised to obtain the information sheet giving more details in regard to this vacancy from the Registrar, University, Milner Park, Johannesburg, South Africa, with whom applications should be lodged not later than 31st January, 1955.

COLUMBIA UNIVERSITY
SCHOOL OF MINES
HENRY KRUMB SCHOLARSHIPS
WILLIAM CAMPBELL FELLOWSHIPS
KENNECOTT SCHOLARSHIP

Applications for the above awards are now invited for the academic year 1955-56. They are available to degree candidates in Mining, Mineral Engineering and Metallurgy.

The Henry Krumb Scholarships, in the amount of $1000 a year, are awarded to B.S., M.S., and professional engineering degree candidates.

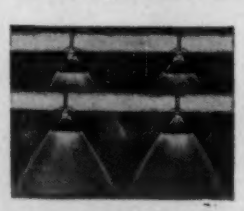
The William Campbell Fellowships, with the value of $1800-$2100 a year, are awarded for graduate study leading to the M.S. or doctoral degree, or for post-doctoral work.

The Kennecott Scholarship is an undergraduate scholarship, restricted to mining students, and has the value of $1000 a year.

In addition to these departmental offerings other University and Engineering School scholarships and fellowships are available to students in the School of Mines.

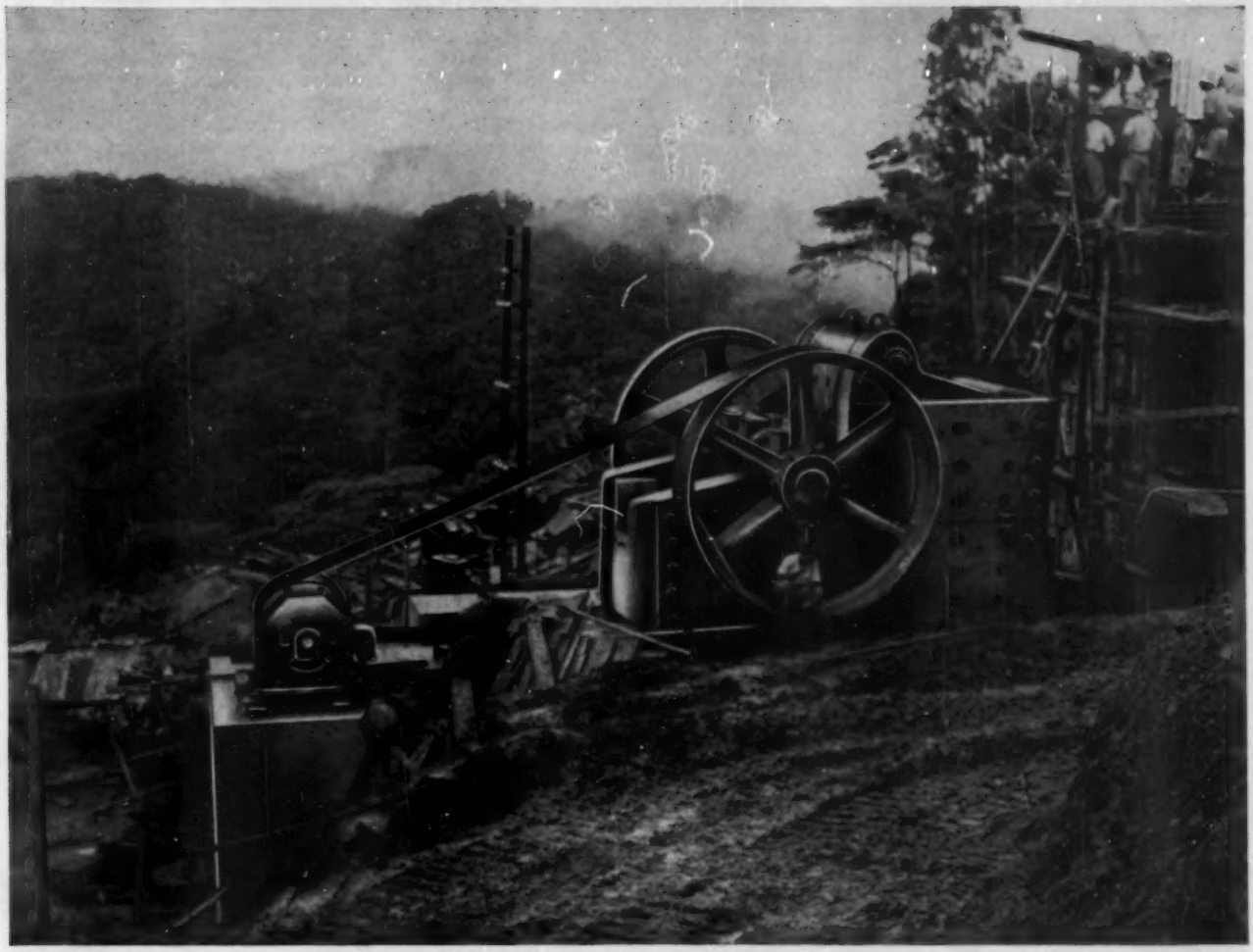
Application blanks and further information may be obtained from the Office of University Admissions, Columbia University, New York, 27, N. Y. The closing date for applications is February 21, 1955.

CONCENCO Spray Nozzles Easily Installed Without Threading



For sheet flow spray arrangements, CONCENCO Spray Nozzles offer fast, economical installation. You simply drill oversize holes, clamp on and get results. The nozzles are easily aligned, and are made in two sizes, for 1" to 2" pipe and for 2" to 4" pipe. Send for full information.

THE DEISTER CONCENTRATOR COMPANY
923 Glasgow Avenue Fort Wayne 3, Indiana



Massive Construction for peak production

Traylor Type S Jaw Crushers . . . the most massive jaw crushers ever built . . . are scientifically engineered to stand up to the most severe production schedules in the mining field. Type S crushers are "Traylor-Made" with Traylor's famous curved jaw plates to meet your particular requirements and specific operating conditions. Available in seven sizes, with feed openings from 36" x 42" to 60" x 84", Traylor Type S Jaw Crushers offer capacities up to 1,000 tons per hour.

Bulletin 125 outlines the exclusive design features of Type S Jaw Crushers and contains full specifications. Send for your copy of this free bulletin today.

TRAYLOR ENGINEERING & MFG. CO.
704 Mill St., Allentown, Pa.
Canadian Mfrs.: Canadian Vickers, Ltd., Montreal, P. Q.

A Traylor leads to greater profits

SEND FOR BULLETINS
. . . just mention the Traylor Equipment that interests you.

SALES OFFICES · NEW YORK · CHICAGO · SAN FRANCISCO

MEN AVAILABLE

(Continued from page 2)

Executive Assistant Mining Investments Economic Geologist, college graduate, 35, married. Expert negotiator of leases, options, and investment evaluations. Field experience in iron ore, metals, petroleum, exploration contract drilling, and development. Worked in Central America, U.S., and Canada. Speaks, reads, writes Spanish. M-113.

Geologist, M.S. New York University. Six years experience in seismograph interpretation. Desires position as geologist or geophysicist. M-114.

POSITIONS OPEN

Junior Engineer, mining or civil engineering graduate, for field work on gold dredging project. Must be single. Two-year contract. Salary, $3600 a year plus room and board. Location, Columbia. F44-S.

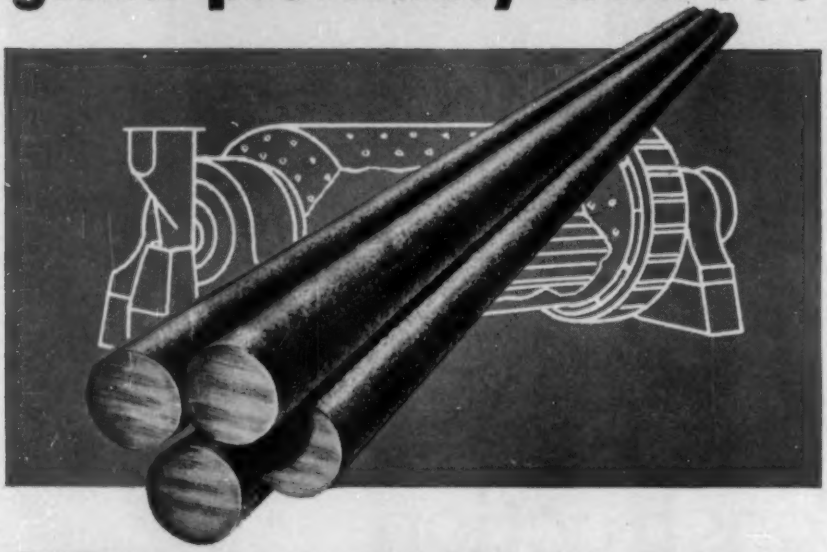
Metallurgical Engineer, to take charge of the metallurgical problems of a mining operation. Should have thorough knowledge of flotation, cyanidation, lixiviation, and if possible, some knowledge of running a sulphuric acid plant. Accomodations for man and wife only. Salary open. Location, Chile. F172.

Mining Geophysicists, under 30, to take part in pioneer geophysical exploration and development program. Good background in physics and electronics essential. Salary, $6000 a year. Location, West. W290.

Mining Engineer, 30 to 40, minimum of 5 years experience in metal mining (not coal) practices and knowledge of metal mining and exploration. Will keep abreast of developments in mining department and keep executive concerned informed; will organize and present studies on operating results and special mining projects; follow up special projects requiring knowledge of mining and exploration procedures and familiarity with sources of information. Some traveling. Headquarters, New York, N. Y. W762.

Engineers. (a) Chief Mine Safety Engineer, graduate mining engineer, with minimum of 8 years experience in mining, 4 of which must have been in underground mining work, preferably supplemented by training and experience in quarry operations, mine safety work, and accident prevention. Salary, $7200 to $8400 a year. (b) Safety Engineer, grade I, 35, graduate mining engineer, with minimum of 6 years experience, 2 of which should have been in underground mining. Must be familiar with state safety laws pertaining to mine operation, tunnel and caisson construction in free and compressed air, explosives and fireworks, transportation of dangerous articles, and the mine safety regulations of the U. S. Bureau of Mines and other mine safety authorities. Must be able to qualify for a grade A blaster's permit. Will be under the direction and supervision of the chief mine safety engineer, serve as his first assistant, and be responsible for the effective operation of the field activities of the section and the work of the mine safety inspection. Salary, $6100 to $7100 a year. (c) Safety Engineer, grade II, 35, graduate mining engineer, minimum of 6 years experience, 2 of which should have been in underground mining; familiar with state safety laws pertaining to mine operation, tunnel and caisson construction in free and compressed air, explosives and fireworks, transportation of dangerous articles, and the mine safety regulations of the U. S. Bureau of Mines and other mine safety authorities; some experience in the use and handling of explosives. Will be under the direction and supervision of the chief mine safety engineer or the safety engineer, grade I, to direct the work of the mine safety inspectors and participate in the development and activation of the engineering, educational, and enforcement programs of the section. Salary, $5400 to $6100 a year. Location, New Jersey. W680.

grind profitably with . . .



CF&I GRINDING RODS

Profits in mineral dressing are based on efficiency and long equipment life—the same reasons that are responsible for the wide acceptance of CF&I Grinding Rods. Rolled from special analysis steel, machine straightened with square-cut ends, CF&I Grinding Rods are a grinding medium of top performance and value—they wear evenly and resist abrasion.

Other CF&I Steel Products for the Mining Industry

Cal-Wic Industrial Screens • Wickwire Rope • Rock Bolts
Grinding Balls • Light Rails and Accessories

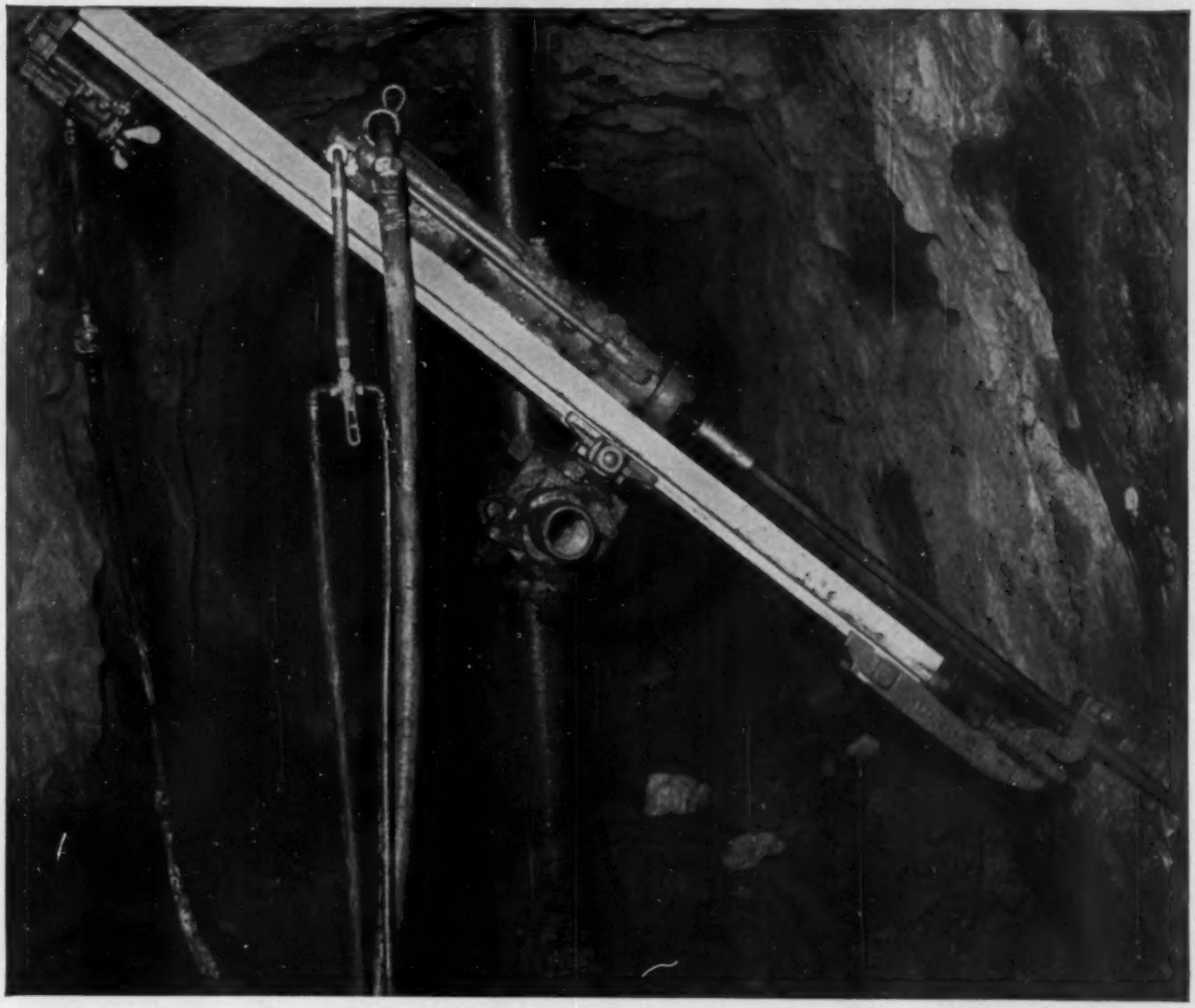
CF&I GRINDING RODS
THE COLORADO FUEL AND IRON CORPORATION

2473

Albuquerque • Amarillo • Billings • Boise • Butte • Casper • Denver • El Paso • Ft. Worth • Houston
Lincoln (Neb.) • Los Angeles • Oakland • Oklahoma City • Phoenix • Portland • Pueblo • Salt Lake City
San Antonio • San Francisco • Seattle • Spokane • Wichita • CANADIAN REPRESENTATIVE AT: Vancouver

First in the field!

New Gardner-Denver 4½" Deep Hole Drill



new 4½" hammer diameter for heavy-duty underground drilling.

new drilling power for deeper long hole drilling.

new drilling capacity for handling larger diameter bits.

Big brother to the popular Gardner-Denver SFH99 Deep Hole Drill, the new 4½" SFH123 has been engineered for use with Ring Seal Shank and Sectional Drill Rods. Compact screw feed guide shell handles steel changes up to 5'. Write us today for additional specifications.

The new
Gardner-Denver
SFH123
4½" Deep Hole Drill

SINCE 1859

GARDNER-DENVER

THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

Gardner-Denver Company, Quincy, Illinois
In Canada: Gardner-Denver Company (Canada) Ltd., 14 Curity Avenue, Toronto 16, Ontario

ATLANTIC
GULF
MEXICO
CUBA
JAMAICA
VENEZUELA
COLOMBIA
GUIANA
BRAZIL
BOLIVIA

ON January first of this year, Dorr-Oliver Incorporated became a corporate entity through the merger of The Dorr Company, Engineers and Oliver United Filters Incorporated. Not a merger in name only, the combined staffs, engineering skills and facilities of the two organizations are being welded into a single unit, with a vastly increased capacity to serve on a worldwide basis.

Both companies have their roots in gold ore metallurgy. The Dorr Company was founded by John Van Nostrand Dorr on his early inventions, the first of which was developed in 1904 to solve the problem of mechanical classification of gold ores. Oliver United had its beginning in 1907 with the development of the first successful continuous vacuum filter by Edwin Letts Oliver and its practical application to the cyanide process. Since their inception, both companies have grown steadily in technical stature to positions of leadership in their ever-widening and complementary, fields.

This cumulative, combined experience . . . coupled with a progressive faith in the future . . . is the strength of Dorr-Oliver. For present and future clients alike throughout the world it means better solutions to process problems in those fields of metallurgical, chemical, industrial and sanitational engineering in which Dorr and Oliver have specialized for nearly half a century.

DORR-OLIVER
INCORPORATED
STAMFORD, CONNECTICUT, U. S. A.

Edwin Letts Oliver, Founder and President of Oliver United Filters, at left and John Van Nostrand Dorr, Founder and Chairman of the Board of The Dorr Company, at right. The globe, long symbolic of worldwide operations, stands in the home office of the new corporation in Stamford, Connecticut.

Manufacturers News

New Products • *FILL OUT THE POSTCARD FOR MORE INFORMATION* • Equipment

12 Miles of Plastic

A 12-mile plastic pipe line, said to be longest continuous plastic pipe line in the U.S. was recently installed in Mississippi to carry unwanted salt water from 25 oil wells to a central disposal plant. Pipe was made from Kralastic blend of plastic and rubber

produced by the Naugatuck Chemical Div. of *U. S. Rubber Co.* Fabrication was by Southwestern Plastic Pipe Co. of Mineral Wells, Texas, which extruded the 30-ft lengths of 2 to 6 in. diam line. Joints were solvent welded. For more information on the possibilities of plastic pipe, **Circle No. 1**

OCC Separator

Wilmot Engineering Co. has acquired rights to the OCC Heavy-Media separatory vessel for North American coal applications. Lowered power requirements, less main-

tenance, and 3-product separation are claimed for the six designs to 400 tph capacity. Use of 50-tph capacity pilot plant facilities in Pennsylvania are offered. The *Ore & Chemical Corp.* retains rights to uses other than coal. **Circle No. 2**

Close it in!

Winter weather is a reminder to do something about putting a cab on the deck of that Cat out there. Cutting out winter snow and cold, or summer dust and heat, means more work done more safely because the operator is in the cab and the weather is outside. *Crenlo Inc.* may have the answer, a line of heavy duty cabs easily installed on power machines. Latest is model illustrated for Cat No. 6 shovel loader. **Circle No. 3**

4½-in. Deep Hole Drill

A new deep hole percussion drill with 4½-in. hammer announced by

Gardner-Denver is the big brother of the 4-in. model already in use. Drill uses G-D's ring seal shank and sectional drill rods on guide shell handling up to 8-ft steel changes. Increased drilling speed and power in longholing, as well as larger diameter are claimed gains with new design. **Circle No. 4**

Fastened V-Belts

Open end V-belting and fasteners can supply the economical answer when the right belt is not on hand, or when machinery would have to be dismantled to install an endless

belt. V-belts can be made up in any length with *Flexible Steel Lacing Co.'s* new Alligator fasteners with nylon bushings. An ideal stock item for emergencies. **Circle No. 5**

Scintillation Counter

Recording scintillation counter announced by *Sherwin Instrument Co.*, with airborne and ground applications, has sensitivity better than 100 counts per sec per microroentgen per hr. **Circle No. 6**

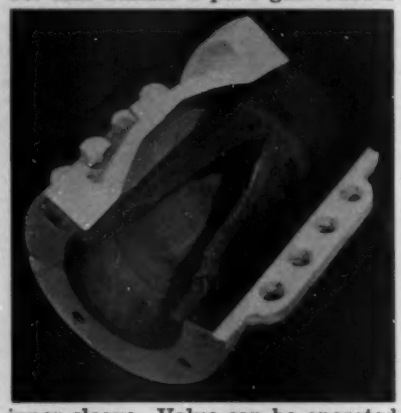
Bigger Rear-Dump

Model C Tournapull now has 22-ton capacity instead of 18, according to *LeTourneau-Westinghouse Co.*,

but the price is unchanged. New body is rated at 14.7 yd struck, 17 yd heaped. **Circle No. 7**

Control Valve for Solids

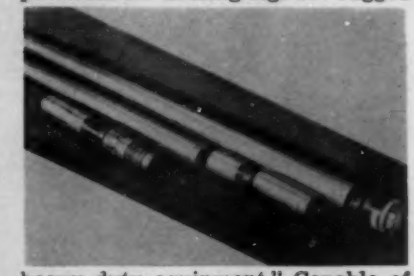
Handling bulky materials and ore pulps may be easier with a control valve marketed by the *Red Jacket Co.* that utilizes a pure gum rubber



inner sleeve. Valve can be operated manually. Pneumatic operation is by introducing air directly into the annular space between rubber sleeve and cast iron body. **Circle No. 8**

Core Barrel

Hoffman Bros. Drilling Co. has introduced the Beaver core barrel to "meet the demand of the newer, more powerful air drilling rigs for rugged



heavy duty equipment." Capable of coring coal as well as many other formations, the heavy duty Beaver barrel offers long life and easy core removal. **Circle No. 9**

News and Notes

Merger of *The Dorr Co.* and *Oliver United Filters* under the name of *Dorr-Oliver Inc.* was effective Jan. 1, 1955. Stamford, Conn., is headquarters of the new corporation . . . *Harnischfeger Corp.'s* small excavator div. is now called the P&H Power Crane & Shovel Div., handling crawlers to 3½ yd, truck cranes, soil stabilizers, and loaders. The P&H Electric Shovel Div. handles all electric machine sales from the model 1055 electric shovel through the 10-yd model 1855 dragline . . . Research Corp. has formed a wholly owned subsidiary, *Research-Cottrell Inc.* to operate the electrical precipitation part of its business. Carl W. Hedberg heads the new organization . . . *H. K. Porter Co.* acquired more than 97 pct of the stock of Riverside Metal Co. as part of recent expansion.

Free Literature

(21) METAL QUENCHING: *Gulf Oil Corp.'s* 24-page booklet on the quenching of metals is illustrated with many charts and graphs depicting cooling curves, cooling rates, effect of bath temperatures, agitation curves, hardness penetration curves, and transformation diagrams. Also included are typical case studies.

(22) GAS ALARMS & ANALYSIS: *Mine Safety Appliance Co.'s* complete line of combustible gas analyzers and alarms are described in a 20-page brochure that contains part-by-part descriptions of the components of MSA's analyzers. Actual installations are fully covered and a method of designing alarm systems is shown schematically.

(23) IRON CASTINGS: "Glossary of Terms for Producers and Users of Iron Castings" from *International Nickel Co. Inc.* contains 36 pages and explains more than 150 technical terms relating to ferrous and nonferrous castings. Useful to the designer, machinist, and purchaser of castings, as well as a foundry man.

(24) CYCLONES: A 12-page catalog illustrating four basic model Krebs cyclones for wet Classification from *Equipment Engineers Inc.* describes molded pure gum replaceable lining and integral two-stage cylindrical design. Catalog also contains data on role of cyclones in classification and presents full details of specific applications of each model for varied objectives.

(25) ROK-BITS: An 8-page bulletin from *Brunner & Lay* has two charts illustrating every Rok-Bit manufactured. One chart covers shoulder union types and the other covers bottom drive bits. Detailed recommendations are made for the use of every bit—thread type, size of steel, and machine normally used.

(26) LABORATORY SERVICE: A "Welcome To" folder from *Sam Tour & Co. Inc.*, independent research, development, and testing laboratory in New York City, answers the 12 most common questions that enter the minds of clients and prospects.

(27) HAULAGE: *Euclid Road Machinery Co.'s* form 120-R is devoted to the 22-ton model TD rear-dump truck. Payload is 44,000 lb and capac-

ity 14.8 cu yd struck measure with standard body, 16.2 cu yd heaped. Photographs show safety, speed, power, and easy operating features that mean "lower hauling costs."

(28) ELECTRIC MOTORS: Booklet from *U. S. Electrical Motors Inc.* is a brief presentation of the complete line. Illustrated are the 20 principal types of improved U. S. motors.

(29) AC CRANE CONTROLS: Bulletin GEA-6112 from *General Electric* covers ac crane controls, cab and floor operated, for hoist, bridge, and trolley operation. This redesigned and expanded line requires less than half as much depth and height and has improved maintenance and installation features.

(30) LIME SLAKERS: *Hardinge Co.* has issued a 4-page bulletin covering lime slakers that briefly describes the continuous milk-of-lime process, shows various systems, and covers related process equipment.

(31) SCRAPER HOISTS: A full line of air and electric hoists for handling bulk materials of all types is described in a comprehensive catalog from *Ingersoll-Rand.* Outstanding features of each type and size are carefully outlined along with specifications, capacities, sizes, symbols, and accessories available. A variety of operations in the mining industry for which these heavy duty units were originally designed is illustrated.

(32) VIBRATING SCREENS: *Bonded Scale & Machine Co.* has two illustrated 8-page bulletins. One gives details about heavy duty four-bearing eccentric screens for heavy ore and rock scalping as well as for high tonnages in fine screening, wet or dry. The other bulletin covers two-bearing, eccentric weight general purpose screens.

(33) PRECIPITATOR: *Research-Cottrell Inc.* has a 6-page bulletin describing the MI Rapper for automatic and continuous cleaning of collection electrodes in a Cottrell electrostatic precipitator.

(34) GAS ENGINES: A colorful bulletin describing and illustrating the 225 to 675 hp Le Roi L3460 and L4000 engines uses cutaway views and photos to show design features such as the integral V-12 cylinder block design, counter balanced crankshaft, and hydraulic valve lifters. Le Roi Div. of *Westinghouse Air Brake Co.* calls these engines "the most modern and powerful gas-butane-gasoline engines in their class."

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after April 15, 1955 — if mailed in U. S. or Canada

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	Students should write direct to manufacturer.						

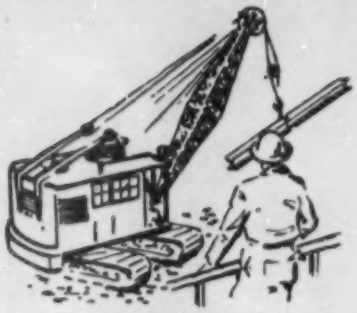
Name_____ Title_____

Company_____

Street_____

City and Zone_____ State_____

(35) DESIGN & ENGINEERING: *Vitro Engineering Div.*, Vitro Corp. of America, is engaged in the design and engineering of processing and



other technical facilities for Government and industry. Recent projects are described and illustrated in "Speaking of Engineering..."

(36) STORAGE BINS: *Neff & Fry Co.'s* 29-page technical brochure on concrete stave storage bins contains photos of typical installations; detail drawings of stave, rods, and lugs; and bin capacities per foot of height.

(37) BENEFICIATION EQUIPMENT: Bulletin No. 11 from *Western Machinery Co.* gives a rapid view of the full line of WEMCO equipment which includes: classifiers; hydroseparators; thickeners; conditioners; attrition machines; Fagergren flotation machines; a line of Heavy-Media separation plants, Mobil-mills, separators and densifiers; as well as pumps, and laboratory equipment. Photographs, diagrams, and brief specifications outline range of units available for each type of machine.

(38) MOTOR PULLEY: Complete redesign of the standard line of *Reeves* Vari-Speed motor pulleys is described in a 28-page multicolor catalog. Redesigned motor pulley, engineered for new NEMA frame motors, but also usable with the old NEMA motors, is available in eight sizes, ranging from ½ to 15 hp and in speed ratios as great as 4:1.

(39) SWIVELOADERS: Used for loading or storing bulk materials, *Stephens-Adamson's* Swiveloaders handle practically any dry granular or lump material. These centrifugal units throw material 35 ft or more and swivel horizontally and vertically for complete directional control.

(40) CLAMSHELL BUCKETS: Among features stressed in *Erie Strayer Co.'s* bulletin on clamshell buckets are design—a combination of block and tackle and lever arm, one-piece welded heads that prevent wobbling and save wear, lower headroom, and a reeving system that adds 50 pct to cable life.

(41) EARTH-MOVING: Big earth-moving returns from a small investment are possible when an *Allis-Chalmers* model WD-45 wheel tractor is equipped with Henry backhoe and other Henry hydraulically operated attachments. Two-color, 8-page, illustrated catalog contains specifications and other data.

(42) VOLUME FAN: *Chicago Blower Corp.'s* bulletin MD-101 gives detailed specifications on a large volume fan, available with direct or V-belt drive, for standard or heavy duty service. MD fans can be supplied with six different types of coatings to meet any acid or corrosive fume condition.

(43) PORTABLE CABLES: Claimed "the most dependable power cable available for continuous miners," *Hazacord* bulletin H-461 lists cable construction for Jeffrey Colmol, Joy, and Carbide machines.

(44) FLOCCULATING AGENT: *Dow Chemical Co.* has announced a flocculating agent that may revolutionize solids removal from water solutions. Separan 2610, effective in dosages as small as one part 2 million parts of dispersed solids has decreased material losses as much as 80 pct and increased total production recovery as much as 5 pct and speeded filtration in commercial use.

(45) SPIRAL RAKE THICKENERS: *Denver Equipment Co.'s* 12-page illustrated bulletin T5-B5 features Denver's simple mechanical rake and settling unit for the separation of solids from liquid. Given are dimensions, specifications, and capacities of steel, wood, or concrete thickener tanks in sizes from 3 to 80 ft.

(46) WORK TEAMS: *International Harvester Co.'s* 47-page catalog CR-758D covers tractors, tractor equipment, rubber tired units, and power units. Brief specifications are given and drawings and photographs show how these units separately or in combination "make the hardest working work teams in the world!"

(47) COMPRESSORS: *Chicago Pneumatic Tool Co.'s* portable rotary compressors are available in 125, 210, 365, and 600-cfm sizes. Weighing less than piston type units of half their capacity and occupying 30 pct less space than equivalent piston types, these compressors are already giving "thousands of trouble-free service hours" in mining.

(48) END-DUMPS: *Kenworth Motor Truck Corp.* has engineered the 802 and 802-A heavy duty end-dump trucks for safety in every detail. Bulletin on these 24-ton, 16 to 19-yd models shows all controls within easy reach, points out simplified dash and effective warning devices.

(49) MAGNETIC SEPARATION: Bulletin from *Stearns Magnetic Inc.* lists a wide line of magnetic separation and power transmission equipment. Research laboratory facilities are also explained.

(50) PUMP SELECTOR: Impeller design in *Nagle* industrial pumps is not standardized, but is available in four types plus the two-vane model to make these units suitable for "difficult and abusive applications found in industrial and process plants." Bulletin 952 contains specifications and applications.

(51) JAW CRUSHER: *Traylor Eng. & Mfg. Co.'s* bulletin 125 on type S jaw crushers. See page 3.

(52) WEIGHING CONVEYOR: For bulletin 301 from *Dwight-Lloyd Inc.* on the Transportometer. See page 92.

(53) SCINTILLATOR: Prospecting for uranium? See description of model 117 made by *Precision Radiation Instruments Inc.* on page 2.

(54) CALCINE COOLER: For *Stearns-Roger* bulletin on the improved calcine cooler which is shown on page 86.

(55) NEAR-SURFACE SEISMIC DATA: For *Houston Technical Laboratories'* bulletin No. S-303 on making shallow seismic surveys. See inside back cover.

(56) CHAIN & CONVEYOR CATALOG: For *Wilmot Engineering Co.'s* catalog 513. See page 91. For bulletin 512 on ductile iron castings, circle 57.

FIRST CLASS
PERMIT No. 6433
Sec. 34.9 P.L.&R.
New York, N. Y.

BUSINESS REPLY CARD
NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

3c.—POSTAGE WILL BE PAID BY—

MINING ENGINEERING

29 WEST 39th STREET

NEW YORK, 18, N. Y.

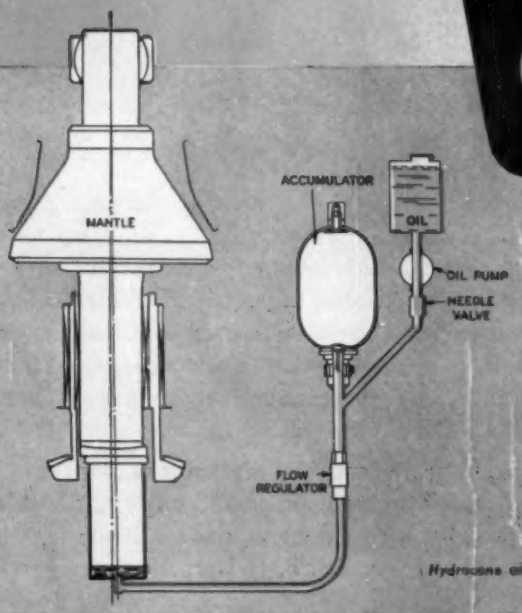
Speed-Set Hydraulic Adjustment Affords

One Man...One Minute Product Control

Quick, Accurate Product Size Adjustment — No dismantling and no auxiliary equipment are required to change from one product size to another. Changing is instantaneous and precise with *Speed-Set* control.

Simplified Compensation for Wear—Compensating for wear on concaves and mantle is equally as fast and convenient. A push of a button on large *Hydrocone* crushers or a move of the hand control on smaller sizes does the job.

Fast Emergency Unloading and Tramp Iron Protection — If crusher stops abruptly because of power failure or other emergency, *Speed-Set* control facilitates fast clearing of crushing chamber.



How Speed-Set Control Works

Mainshaft assembly is supported on hydraulic jack. Oil pumped into or out of jack raises or lowers crushing mantle.

When tramp iron enters crushing chamber, oil from jack is forced into accumulator, allowing mantle to lower. Automatic reset returns cone to original setting after tramp material is passed.

For complete information, see your A-C representative or write Allis-Chalmers, Milwaukee 1, Wisconsin. Ask for Bulletin 07B7145B.

A-4478

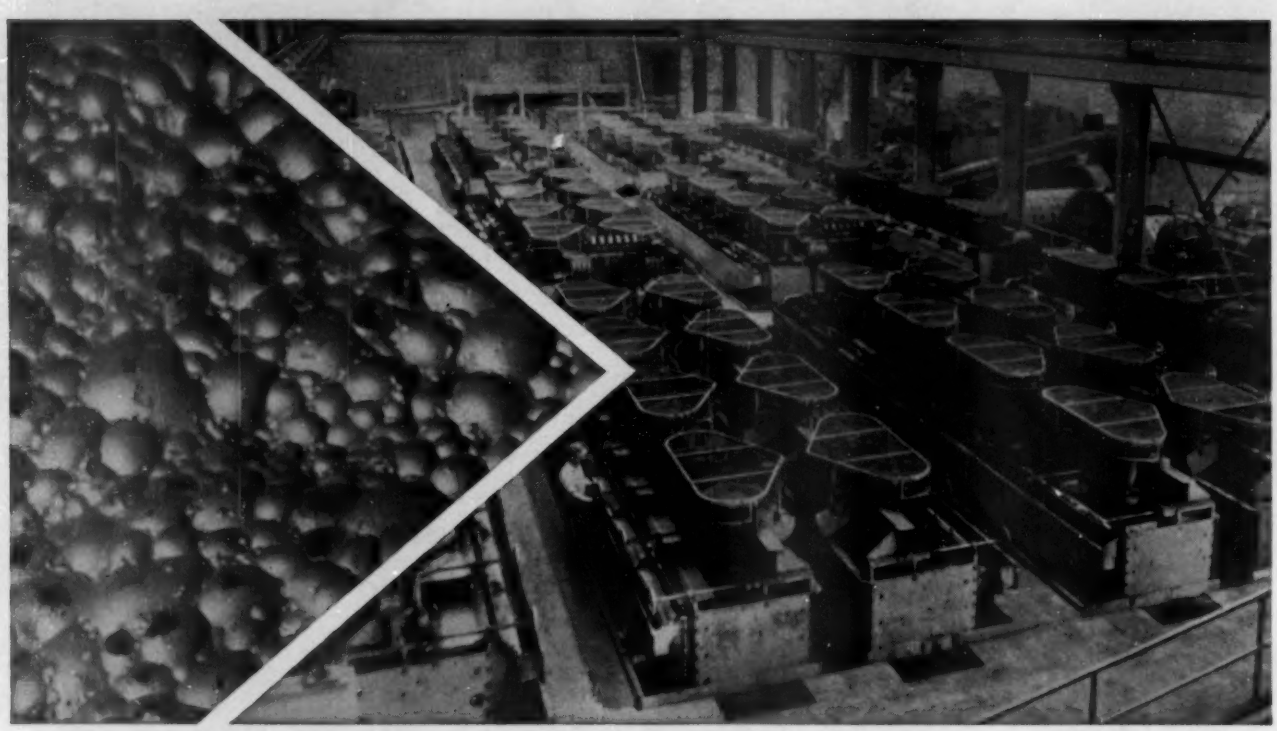
Hydrocone and *Speed-Set* are Allis-Chalmers trademarks.

ALLIS-CHALMERS

DOW

DOWFROTH 250

BUILDS BETTER FROTH AT LOWER COST



This quality frothing agent by Dow raises concentrate grade and increases recovery —with less frother consumption!

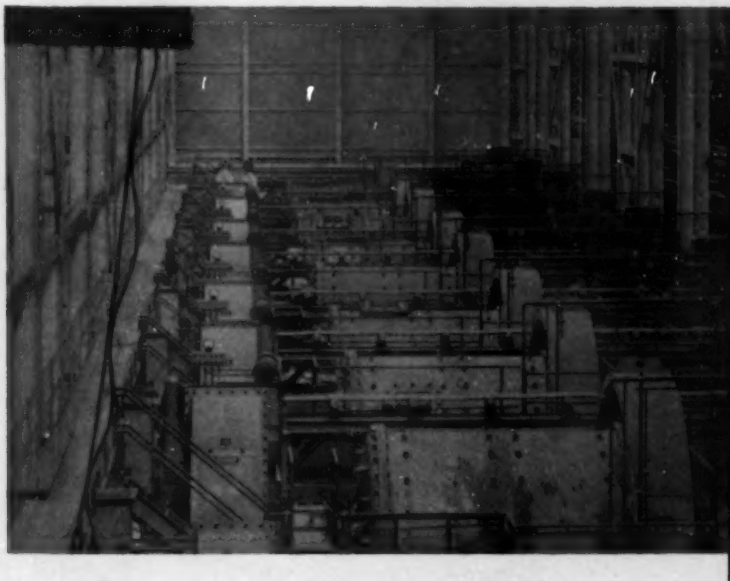
Dowfroth® 250 in many mills today is producing improved metallurgy with as little as one-fourth the consumption of previous frothers used. These are not just laboratory tests, but full-scale mill results. This could mean increased profits and lower operating costs in *your* mill, too.

Dowfroth 250 is easy to use—requires minimum conditioning for stage addition. Its water solubility permits accurate regulation as a water solution if you prefer this method. And it demonstrates little or no collecting power, which allows your operator to regulate frother and collector independently. This hard-working frother by Dow also spares the rubber covered parts on your flotation machines—shows minimum swelling and deterioration to save you money in maintenance.

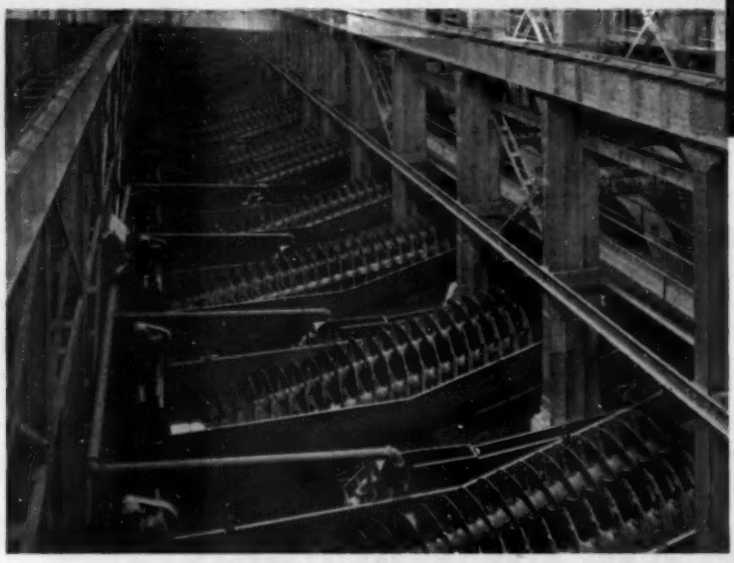
Prove the economy and efficiency of Dowfroth 250 in your own mill by using a test sample with our compliments. Write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. OC 834I-1.

you can depend on DOW CHEMICALS

DOW



copper company again selects this cost-cutting team of MARCY Mills and Akins Classifiers



HAS USED TOTAL OF 114 MARCYS AND 116 AKINS

This leading copper company bought its first Marcy Mill in 1918 and its first Akins Classifier in 1925. Based upon the successful performance of this equipment they have continued ordering Marcys and Akins for their many plants... have used a total of 114 Marcy Mills and 116 Akins Classifiers. The new mill shown above includes 8, 10′ x 10′ Marcy Ball Mills and 20, 54″ Duplex Akins Classifiers.

Sales Agents:
W. R. Judson, Santiago, Chile
The Edward J. Nell Co., Manila, P. I.
The Ore & Chemical Corporation, 80 Broad Street, New York City 4, New York
Representatives for Continental Europe

The Mine & Smelter Supply Co.

DENVER 17, COLORADO

OFFICES IN SALT LAKE CITY, EL PASO, 1775 BROADWAY, N. Y. C.

REPRESENTATIVES IN FOREIGN COUNTRIES

AND ITS SUBSIDIARY COMPANY **COLORADO IRON WORKS CO.**

Ni-Hard curbs wear of abrasive muck traveling at high speeds and pressures in cyclones used for desliming concentrates. Before starting their operations in White Pine, Mich., the White Pine Copper Co. ordered these Ni-Hard cyclones cast by Staver Foundry Co., Virginia, Minn.

Why a new mine...

WHITE PINE COPPER COMPANY

specifies Ni-Hard for Cyclones

BEFORE INSTALLING UNITS for desliming concentrates, White Pine Copper Company, White Pine, Mich., investigated the performance of NI-HARD® cyclones on the Mesabi range.

White Pine engineers asked users about the wear-resistance of Ni-Hard . . . how the life of Ni-Hard castings compared with that of rubber lined steel or other materials used in cyclones.

Answers received by White Pine boil down to 9 words:

Ni-Hard provides the maximum of abrasion resistance per dollar.

Prove for yourself why mine operators specify Ni-Hard. Try Ni-Hard on *your* tough jobs. Its remarkable resistance to wear cuts downtime of equipment and reduces both operating and replacement costs. INCO TRADE MARK

The completely revised third edition of "Engineering Properties and Applications of Ni-Hard" is now available. Also, the "Buyers' Guide for Ni-Hard Castings." Write for your copies now."

THE INTERNATIONAL NICKEL COMPANY, INC.

67 WALL STREET
NEW YORK 5, N. Y.

INTERIOR SECRETARY DOUGLAS MCKAY recently urged western foresters and conservationists to support legislation aimed at ending mine law abuses. Speaking at the annual Western Forestry Conference, the Secretary said that filing on a marginal mineral claim just to acquire timber would be discouraged if legislation makes it possible for the Federal Government to cut and remove merchantable timber from claims to which deeds had not yet been granted.

Great Lakes iron ore shipments declined about 37 pct in 1954 from the record breaking total of 1953. Ore shipments last year reached 60,793,687 tons, compared with 95,844,449 tons in 1953, or some 35 million tons less.

U. S. MINE PRODUCTION of lead is expected to reach about 315,000 tons for 1954, for the lowest figure since 1934, according to the U. S. Bureau of Mines. While final production estimates are unavailable, the USBM disclosed that total output for the first ten months of last year amounted to 263,400 tons, or 26,300 tons per month. Average monthly production for 1953 was 28,500 tons.

ANACONDA COPPER CO.'s subsidiary, International Smelting & Refining Co. resumed operation of its lead-zinc concentrator at Tooele, west of Salt Lake City and plans to put its lead smelter back in operation. The concentrator was closed during the early part of 1954. Current operation is possible because of continuous mining resumption on the part of United Park City Mines Co. east of Salt Lake City.

Domestic bauxite production by seven leading U. S. producers rose sharply during the third quarter of 1954 to 638,040 tons, according to the Bureau of Mines. It amounted to a 72 pct increase over the second quarter.

APPOINTMENTS WERE MADE recently to a number of new posts created in line with the reorganization survey made of the Bureau of Mines. New positions and the men who will fill them are: Thomas Miller, formerly assistant director for operations, becomes deputy director; Paul Zinner, formerly chief of the Minerals Div., becomes assistant director in charge of programs; Clifford W. Seibel, formerly a regional director, now is assistant director in charge of helium operations; and James Westfield, formerly chief of the Health and Safety Div., now is assistant director in charge of health and safety programs. New Washington headquarters division chiefs are: Charles W. Merrill, Minerals Div.; Louis C. McCabe, Solid Fuels Div.; Roscoe A. Cattell, Petroleum and Natural Gas Div.; Harry F. Weaver, Coal Mine Inspection Div.; E. W. Pehrson, Foreign Div.; and William E. Rice, Administrative Div.

New regional directors in charge of all bureau operations in their areas with the exception of health, safety, and coal-mine inspection are: Stephen M. Shelton, Region 1; Harold C. Miller, Region 2; John H. East, Jr., Region 3; Harold M. Smith, Region 4; and Harold P. Greenwald, Region 5.

Climax Molybdenum Co. has raised the price of its basic product, molybdic oxide, about 10 pct and other refined products proportionately. New price for the oxide will be $1.25 per lb of contained molybdenum.

AMERICAN FIRMS ARE MAKING a strong pitch for the purchase of the entire ilmenite deposits of Ceylon, according to reports from Colombo. An agent from a Calcutta firm that made a successful bid for the first 100,000 tons of Ceylon ilmenite lost out because of inability to open a letter of credit by a specific date. It has been estimated that some 20 million tons of ilmenite sands are available for exploration. Among the U. S. concerns reported to be showing interest are Kennecott Copper Corp., and Pacific Tin Consolidated Corp. Another U. S. outfit is reported not only interested in the ilmenite deposits but in obtaining mining rights in Ceylon for 20 years.

ANOTHER OF THE THREE major hard coal mines closed by Lehigh Navigation & Coal Co. in the Panther Valley of Pennsylvania was reopened. The mine, one of two purchased by the Coaldale Mining Co., has hired about 1300 workers thrown out of work when the mines closed. Coaldale expects to produce about 1.5 million tons of coal annually. A short time ago, the Panther Valley Coal Co. reopened another of the Lehigh mines.

New Idria Mining & Chemical Co., leading mercury producer, has acquired an interest in the Verde Development Corp., uranium operators in the Mojave Desert of Southern California. In addition to acquiring an interest in the company New Idria has entered into a consulting contract with Verde.

HANDLE WITH ABANDON!

No "babying" needed here! "U. S." engineers designed this premium quality hose *specifically* to meet the toughest mining conditions. And it's paid off in performance in open-pit and underground mines around the world.

A universal mining hose, U. S. Matchless® withstands the highest required working pressures for both air and water, and is recommended for high-pressure water cooling of jack hammers as well as for all heavy duty hard rock use. Highly flexible in spite of its great strength, it has demonstrated time and time again its ability to take both use and abuse indefinitely.

Mandrel-made, with a wrapped finish, U. S. Matchless is available in 50 ft. lengths from any of our 27 District Sales Offices, or by writing to the address below. *Whatever* your hose requirements, you'll find it pays to turn to "U.S." There's a job-engineered U.S. Hose for practically every purpose—a staff of "U.S." engineers to assist you in your hose selection.

U.S. Matchless Wire Braid Mining Hose

- tube of high quality neoprene is completely resistant to line oil
- special steel wire braid gives tremendous strength—allows permanent bonding by heavy gauge rubber layer
- an additional layer of rubber under the specially coated rayon breaker protects wire against corrosion should cover be cut or damaged
- cover of carefully selected, tough, brown natural rubber fights off injury from rocks, tools, and heavy equipment

"U.S." Research perfects it..."U.S." Production builds it...U.S. Industry depends on it.

UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION · ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes
Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting

Television Solves Mine Shaft Problem

It may not be Milton Berle, but the television program at the Centennial mine of the Calumet Div., Calumet & Hecla, Inc. adds up to good TV for the mine's employees.

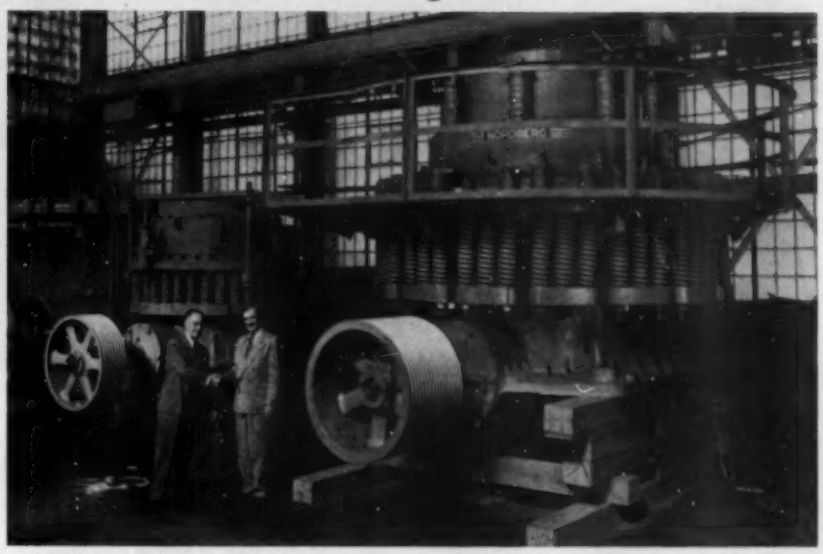
No giveaway program, the show pays off in safety benefits, time saved, and increased efficiency. Television cameras focus on two horizontal sheaves located midway between the rails more than 1200 ft down the Centennial shaft. There is a long, gradual curve in the shaft at this point. The sheaves are necessary to prevent the skip ropes from slapping against the rails and timbers, thus reducing the time the ropes can be safely used.

Before TV, a watchman was stationed in the shaft to warn the hoist engineer when the ropes came off the sheaves. Now, a picture of the sheaves is relayed to a split image monitor at the engineer's surface station. The curved shaft is a result of restricted property lines harking back to the mine's original owner, the Centennial Mining Co.

Gordon Kingstrom, mining captain at Centennial, inspects a television camera trained on horizontal sheave.

The hoist engineer no longer has to depend on a watchman to warn him when cable slips off the sheave. He has his eye constantly on the TV receiver.

Number 5000 at Nordberg

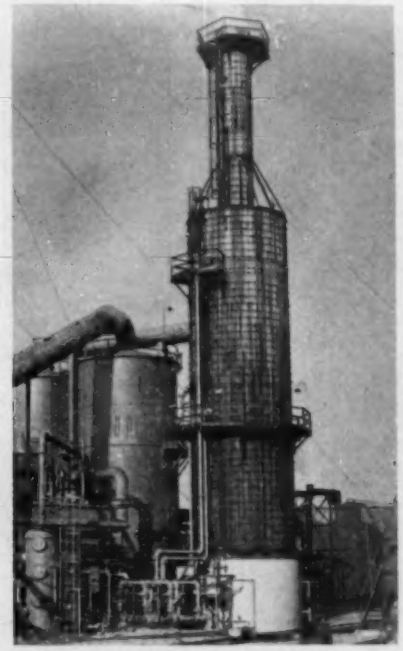


Nordberg president Robert E. Friend congratulates J. B. Bond, assistant general manager and sales manager of Nordberg's Crusher Div., on completion of the 5000th Symons Cone Crusher. The machine is one of 37 super heavy 7-ft Symons Cone Crushers going to the Lake Superior iron ore range for taconite processing. Crusher 5001 on the left is a 4-ft Symons Cone for a slag producer.

Olin Mathieson Gas Scrubber in Action

Increases up to 20 pct have been demonstrated with a two-stage gas scrubbing process being licensed to other manufacturers by Olin Mathieson Chemical Corp.

Olin Mathieson has exclusive U. S. rights to the process, originally developed by Consolidated Mining & Smelting Co. of Canada Ltd. and known as the Cominco SO_2 Recovery Process. Olin Mathieson modified the process for its own use.



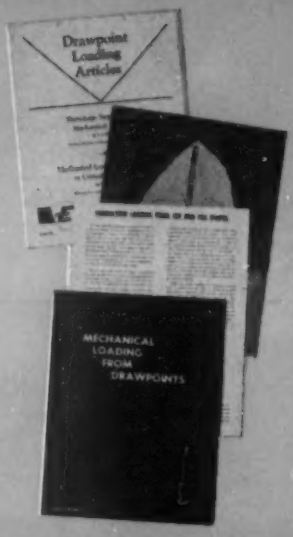
This installation, using the Cominco SO_2 Recovery Process, is at Olin Mathieson Chemical Corp.'s sulphuric acid plant, Pasadena, Texas.

The U. S. firm has established a Western Sulphur & Acids Div. at Little Rock, Ark., and is offering engineering consulting service. It also will undertake design, installation, and initial operation of the process under contract to licensees.

Walter W. Lehle, general manager of the division, points out that even at the most efficient rates of operation contact sulphuric acid plants normally sustain some economic loss in the sulphur which is discharged into the air in exit gases as sulphur dioxide and sulphur trioxide.

The Cominco two-stage scrubber using ammonium sulphate-bisulphite returns this sulphur to the production unit. Part of the acidic values are converted to ammonium sulphate. Plants using the Cominco system can be operated at rates well in excess of normal capacity, because substantially all the unconverted sulphur is recovered and reprocessed. The Cominco process also provides effective abatement in areas where air pollution is a problem, at the same time disposing of the recovered sulphur without water or air pollution.

The process can be used on any gas steam containing sulphur dioxide.



DRAWPOINT LOADING WITH EIMCOS

Drawpoints can, with few exceptions, be used in any mining system. This economical production method is gaining in popularity and has numerous advantages in lower costs, higher production and greater safety.

Eimco has been able to reprint some of the numerous articles from mining journals and has gathered much original material. This information is now available in printed form.

Write for the L-1017 series of publications for information on Eimcos in drawpoint loading.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg.,52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Duluth, Minn. Kellogg, Ida. London, Eng. Paris, France Milan, Italy

888

SYMONS VIBRATING ROD GRIZZLIES for heavy duty big capacity scalping from ½" up to about 4".

SYMONS VIBRATING BAR GRIZZLIES for heavy duty large capacity primary scalping from 1½" upwards.

SYMONS VIBRATING ROD DECK SCREENS for low cost, big capacity screening of wet and sticky material.

SYMONS® SCREENS

...from the *HEAVIEST SCALPING*

...to the *FINEST SCREENING*

SYMONS HORIZONTAL SCREENS for level, positive screening with greater capacity of more accurately sized products . . . ideal for asphalt plants—with drive outside dust and heat.

● *SYMONS VIBRATING SCREENS* have been serving the non-metallic minerals industry for almost twenty years. The wide range of types and sizes enables you to select the *right* screen for your particular application.

These quality screens have gained an enviable reputation for dependability, efficiency and economy... backed by the same high standards of accuracy, design and workmanship, and the same advanced engineering that is used in the manufacture of *all* Nordberg Machinery.

Mail the coupon for further details.

SYMONS "V" SCREENS for big capacity single cut wet or dry separations—even in much finer meshes than possible with conventional screens.

SYMONS... A Registered Nordberg Trademark Known Throughout the World

NORDBERG MFG. CO., Milwaukee, Wisconsin

NORDBERG MACHINERY

NORDBERG

SYMONS SCREENS NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

NEW YORK • SAN FRANCISCO • DULUTH • WASHINGTON
TORONTO • MEXICO, D.F. • LONDON • JOHANNESBURG

MAIL THIS COUPON TODAY

NORDBERG MFG. CO., Milwaukee, Wisconsin ME

Please send me further information on the following screens for coal preparation service:

☐ Symons Horizontal Screens ☐ Symons "V" Screens
☐ Symons Rod Deck Screens ☐ Symons Grizzlies

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

5254

Johns-Manville Opens Southern Rhodesian Mine

The second largest mining and milling operation in Southern Rhodesia opened its doors for business late last year. Rhodesian Asbestos Ltd., with two mines under development, Temeraire at Mashaba and Shamala 4 miles away in the Victoria district, started operations with the pushing of a button by Prime Minister R. S. Garfield Todd.

Rhodesian Asbestos is under the direction of Canadian Johns-Manville Co. Ltd., in association with British Metals Corp. Ltd., Anglo-Huronian Ltd., Southern Minerals & Marketing Corp. (Pty) Ltd., and the Simon I. Patino interests. A central mill has been constructed at Temeraire. Ore from the Shamala mine is transported in 15-ton diesel trucks. Mill facilities include a modern drying and crushing plant and an 8000-ton capacity dry rock storage. The mill proper is housed in a steel, concrete, and asbestos-cement board building 150x64x57 ft, and has a capacity of 125 tph. Bag type filters remove 100 pct of visible dust from air used in the mill.

One of the outstanding features of the mine development is the provision for living and recreation facilities for employees. Forty-nine modern bungalows have been constructed for staff housing. In addition to a swimming pool, club house, and tennis courts available at the mine development, a club house and rest huts have been established at a nearby lake. Living quarters for native employees comprise 202 double units of brick and asbestos-cement board with attendant facilities, as well as seven barracks type units of six rooms each. A native clinic, stores, and kitchens have also been built.

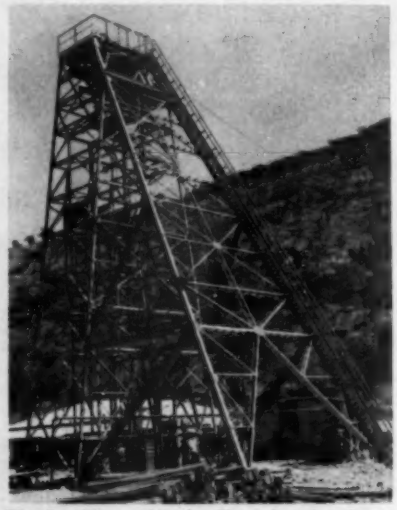
Mine Operation

A steel and concrete shaft with a 200 tph hoisting capacity has been sunk 560 ft at Temeraire and a shaft with 100 tph capacity goes down 520 ft at Shamala. Mining is by diamond drill blast hole and scram drift. Ore is loaded directly into cars by 60-hp scrapers and then crushed underground in 42x48-in. jaw crushers.

Steel and concrete are used for timbering to prevent introduction of foreign material into the fibre. All surface structures—sorting plant for Temeraire ore, and a large mechanical and electrical service building—are constructed of steel, concrete, and asbestos-cement board.

Processed asbestos fibre is trucked from Mashaba to the railhead at Fort Victoria from where it is shipped to Beira, Mozambique, for water transport to Europe and the U. S. Fibre from Mashaba is the chrysotile type suitable for the manufacture of asbestos-cement products used in water and sewage disposal and industrial waste systems.

The new Mashaba mill will take care of the output of two mines. Located at Temeraire, the mill has a capacity of 125 tph. Ore from the Shamala mine is brought to the mill in 15-ton diesel trucks.



The headframe for the Shamala mine has a capacity of 100 tph. Steel and concrete were used throughout in construction.

The huge amount of land occupied by the asbestos operation is shown here. The aerial photo contains the Mashaba plant, European staff houses, and native compounds.

Native employee operates man-hoist at the Temeraire mine. In addition to living quarters in the native compound, there are medical, store, and kitchen facilities provided by the company.

The cottage is typical of the type that Rhodesian Asbestos has constructed for staff members. Elaborate recreational facilities have been installed, including a swimming pool, clubs, and rest camp at a nearby lake.

These 15-ton diesels supply mine-to-mill transportation at the new Southern Rhodesia operation of Canadian Johns-Manville. They are being worked on in the haulage truck section of the mechanical services building.

AMERICAN METAL DISCOVERY——ATLAS AND ARGENTINA——CABINET COMMITTEE——

GEOPHYSICS had the starring roll in the American Metal Co. discovery southwest of Bathurst, at Little River in New Brunswick, Canada. The base metal deposit was pin-pointed by an electromagnetic survey using equipment developed by International Nickel Co. The particular instrument was developed by Stanley Davidson who later formed McPhar Geophysics Ltd. American Metal engaged McPhar to do the follow-up work on the ground. Diamond drill results backed up the geophysical interpretations.

The geophysicists were first airborne in the summer of 1953. By fall enough evidence had been gathered to justify staking but drilling did not start until June 1954.

The ground on which the orebody was discovered was open and could be staked without complications. But most of the surrounding area had been staked during the Bathurst rush of 1953. The Government had granted a year's extension on assessment requirements and the original holders were still on the claims.

American Metal acquired a block of 354 claims in the Little River property with an area 6 miles long and 4 miles wide. They also staked other areas in the vicinity. Some of the earlier claims have been dropped but American Metal now holds about 1000 claims divided into seven groups. The Sheephouse Brook group is located 10 miles south of Little River and is made up of more than 200 claims. While a diamond drill is in operation, nothing important has been reported.

Among the other groups under option is the Roche Long Lac holding in the region of the Bathurst rush. The first two diamond drill holes were disappointing but the company met its option payment and is continuing operations.

American Metal has sold itself on airborne electromagnetic surveys and has three Spartan Air Service helicopters going far afield from the original Little River discovery. In fact, the whole province is being eyed by the company.

Reports of the Little River deposit as of October 16, fixed lead-zinc ore at 3 million tons. Authoritative sources say the property will be a ranking producer. At the moment, preliminary evidence indicates that the orebody is the highest grade big tonnage base metal mine in Canada. Preliminary lead-zinc ore analysis discloses content of 4.0 oz silver, 4.50 pct lead, and 10.50 pct zinc. Some gold and about 0.50 pct copper are present. Copper ore is 1.9 pct, with some 1 million tons already reported.

For services rendered in the original discovery, Inco will have a 25 pct interest in the property.

◆◆◆◆◆◆

SEVERAL reasons have mitigated against investing in Argentina under the Peron regime. Probably the most significant deterrent has been the right of local government to expropriate property. Remarks by Floyd B. Odlum at a recent meeting of Atlas Corp. stockholders hint at a possible change in the economic climate of the South American country.

It seems that Argentine representatives approached Mr. Odlum last January on the possibility of his undertaking the development of the Neuquen oil field. As a result of negotiations, a work and service contract may be evolved under a special contract law to be passed by the Argentine Congress. Under the contract Atlas will probably construct a pipeline and develop the fields for the Government but not actually own them. Rather, they will be managers. The plan also involves the use of blocked pesos. Argentine businessmen will be invited to join the venture.

The study made by Atlas also developed a latent interest in Argentine uranium. Mr. Odlum is not disclosing specific plans but it may be safely assumed that Atlas will eventually do something in that direction. Atlas uranium activities have been bounding ahead at a good clip. In addition to the acquisition of the huge discovery made by Vernon Pick, now called the Hidden Splendor mine, Atlas bought through its subsidiary, Wasatch Corp., shares in Lisbon Uranium Corp. The uranium company's market value is in excess of $3.7 million. Atlas paid about $470,000 for its shares. Atlas also has 180,000 shares of Standard Uranium Corp.

◆◆◆◆◆◆

TWICE in the last 15 years the U. S. has been drawn into armed conflict without adequate supplies of strategic materials to bolster its war effort and in both cases the cost for disruptive expansion programs was enormous. This matter of history was uppermost in the minds of the President's Cabinet committee on mineral policy in preparing its report.

The goal set forth by the committee is the development of an orderly and vigorous development of domestic resources. One of the basic needs they feel, is a complete survey of stockpile objectives and establishment of new long-range objectives to assure adequate stocks which could reduce or eliminate wartime shortages. Another suggestion is the review of tasks that need to be carried on to build and maintain the mobilization for metals and minerals.

Recommendations concerning domestic resources were: the tax structure as it relates to the discovery and production of minerals should be periodically reviewed, eliminating where possible any roadblocks to development; financial assistance for exploration, such as given by the Defense Minerals Exploration Administration, be continued; Interior Dept. activities that precede or supplement private exploration, as geologic and topographic mapping, be speeded up; the Interior Dept. should expand exploration in the national interest where private enterprise is unwilling to do the work; revision of mining laws be made to encourage newer methods of exploration; and that the Interior Dept. intensify research aimed at development of latent resources.

The committee also suggested that Secretary of the Interior Douglas McKay establish contacts where necessary to promote closer cooperation between Government and industry. The Cabinet committee was composed of: Mr. McKay, chairman; Secretary of State Dulles; Sinclair Weeks, Commerce Secretary; and Arthur Flemming, Director of Defense Mobilization.

◆◆◆◆◆◆

AFTER a rather dismal beginning last year, the steel industry closed out 1954 with a sudden, healthy upsurge that for the most part could be traced to the widespread public acceptance of the 1955 automobile models. Several steel industry spokesmen interpreted the rise in production as a good sign of better days in 1955. On another, probably more significant front, steel men were encouraged by what appears to be an improvement in the broad base of consumer demand.

Generally speaking, most conservative prophets are apt to go slowly with high-flown predictions, but the usual rash of year-end forecasts ran the gamut. Significantly, though, two leading steel executives predicted that production this year will jump about 10 to 14 million net tons over last year. Even the less encouraging statements were couched in terms that promise that this will be a good year for the steel industry. Construction, enjoying its greatest boom, appears to be headed for another good year. If business continues to improve as it has, public confidence may even require a revision upward of current projected plans. Defense outlays, at the very least will be equal to 1954 and some experts think they will be even greater.

Inventory during 1954 fell well below normal minimums. Thus replacements will be one of the important factors this year. How intense replacement will be is a matter for speculation at this point, the economists feel. A number of orders have come into sales offices with *urgent* written all over them, suggesting that until now many buyers have been buying on the basis of last minute needs.

Some forecasts place production at an average of 84 pct of capacity during 1955. With only a 16 pct production reserve on hand, buyers will have to take a good look at policy. The reserve would not mean a similar percentage available in terms of steel products.

The general feeling for the first quarter of this year is that the current demand for finished products will continue without abatement. Another group, only slightly less conservative, feels that the first half of 1955 should be better than the similar period last year. Another factor to be considered is the expected Government aid to railroads which may stimulate car buying and other replacements on the roads. Railroads have been spending in relation to income—not good for the steel industry. But no recovery in railroad buying is expected which will match recovery in other areas of the economy.

ROAN Antelope and Mufulira copper mines in Northern Rhodesia have taken the big step in their fight to revise conditions of advancement for African natives. In a letter announcing the termination of contract to the Northern Rhodesian European Mine Workers' Union, the copper mining companies categorically rejected the clause forbidding the promotion of a negro to a white man's job.

However, the debate is not that simple. The copper companies realize that it would be impossible to hand over a job in toto now held by a European, a term used to describe any person of white blood, considering the present standard of native pretraining. The companies want to fragment the jobs, break them up into small pieces to fit the abilities of the personnel to be advanced. They also want to keep wages for native employees in the new positions within the existing scale.

The union has attempted to forestall the move to advance the Africans by insisting that a negro taking a white man's position must receive equal pay. The companies have been fighting hard to overcome this stipulation. The copper firms have also promised, and are willing to have it inserted in the contract, that no white will be discharged to make room for a negro or group of negroes.

Negotiations started in May 1953 with the European Mine Workers' Union. In February 1954 the talks were expanded to include the European Salaries Staff Assn. and the African Mine Workers' Union. In July 1954 the European Mine Union withdrew and the Northern Rhodesian Government set up a board of inquiry under Sir John Forster. The Northern Rhodesia Copper companies accepted the report and the companies invited the European Union to start renegotiation of the existing contract.

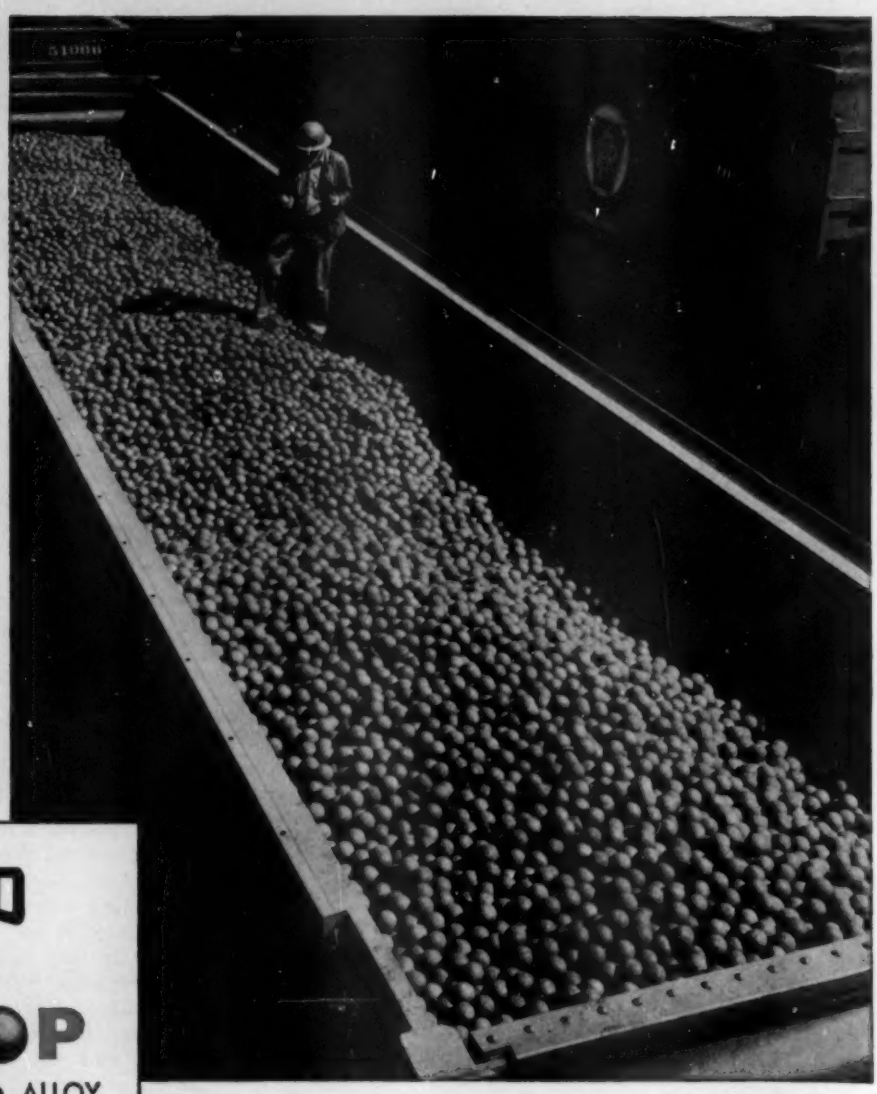
The Forster Board stated: "We find the conclusion inescapable that the establishment of the principle of awarding to any African so promoted the European rate of remuneration would disrupt the African wage structure throughout the Federation and seriously threaten the national economy . . . . We cannot hold that advancement based on differential rates is unfair, specially having regard to the companies' readiness to guarantee the unreduced employment of all their European employees . . . Nor . . . can we hold that there is adequate justification for the fear that the competition may become unfair in the future . . . European workers will have ample time to adjust themselves and their families to the degree of advancement that is to be expected.

"Africans will be unable within the foreseeable future to climb so fast and so far as to endanger European Employment . . . We come therefore to the conclusion that reasonable fragmentation is necessary . . . The solution of the African advancement problem at a very early date is imperative."

Later reports state that some of the copper companies are willing to compromise on the matter of pay. A few of the mines may go along with the idea of equal pay for whites and Africans handling similar work. An obvious outcome may be the necessity of a more elaborate training program and the advancement of fewer negroes.

M. A. Malzhin

Ready to Roll for a Longer Grind



SHEFFIELD

ARMCO

MOLY-COP

TRADE MARK

COPPER • MOLYBDENUM • ALLOY
GRINDING BALLS

This carload of Moly-Cop Grinding Balls might be headed to any one of hundreds of destinations around the world. Sheffield ships them everywhere grinding is part of the industrial picture.

Wherever they go, they'll do a better grinding job. Fewer chargings will be required. Less down time. Less frequent freight bills. Money saved.

That's because Moly-Cop Grinding Balls keep their spherical shape longer. Sheffield's special alloy of steel, copper and molybdenum is just the right "recipe" for longest resistance to wear, chipping and abrasion. There's a big difference in grinding balls—and it will show up on your profit sheet when you use Moly-Cop Grinding Balls.

We're ready with the best grinding ball—plus engineering counsel on how it can best save money in your operation. A call will get you all the facts.

SHEFFIELD STEEL
DIVISION
ARMCO STEEL CORPORATION
SHEFFIELD PLANTS: HOUSTON KANSAS CITY TULSA

EXPORT REPRESENTATIVES: ARMCO INTERNATIONAL CORPORATION • Middletown, Ohio

Drift of Things

A IS FOR ATOM, a phrase that might well become the first page of the primer in 1965, actually is a film produced by General Electric Co. This film, reviewed on page 86, was shown as part of the Atoms for Peace exhibit by the Atomic Industrial Forum Inc. in New York recently. Offering a minimum of sabre rattling and a maximum of peaceful application, the exhibit was refreshing—and startling in its matter of fact acceptance that the atom in industry is here to stay as a daily tool.

Emphasis in the exhibit on atomic power possibilities might superficially be taken as evidence that someone else 'has it in for coal' although a serious look into the future gives hope that coal may more than come into its own again, perhaps in ways as startling as atomic power. The exhibit incorporated the displays prepared by the U. S. Information Agency to go to India and Pakistan and show that the U. S. is not preoccupied with the boom of the atom—but rather with the whir of the atom powered turbine and the hush of medical radiation applications in store ahead. A comic book given out at the showing approached the betterment of lay knowledge of atoms and implications colorfully but factually. Lurid appearance or not, this book dreamed up by General Electric is one way to reach a group important numerically, and perhaps the only way to reach people who don't like to tackle Einstein.

This all reminds us to remind the reader that in the November 1954 AIME section of MINING ENGINEERING there was word that the Directors had given the green light to formation of divisional committees on matters atomic. The IMD has a committee already functioning and formation of others may be expected.

A STORY out of the public relations agency for a finance company packed a jolt. This outfit, long known as one of the top "dollar down, dollar when we catch you" people in the auto finance field has laid out a radically new merchandising plan with a big machine tool company. Phrases reminiscent of established consumer advertising ring throughout the release—monthly rentals to write off as expense . . . lease with option to buy . . . installment plan with monthly payments . . . payments geared to Paying As You Depreciate under the new tax law. This last P-A-Y-D plan (and if there isn't a copy writer's brain child) was tailored to the so called sum of the digits method of depreciating equipment, the fastest method allowed.

Seriously speaking, this plan is geared to the new, faster depreciation tax schedule, which in turn may be said to mesh with an industry-wide trend to tackle the question of equipment replacement and obsolescence with more money than at times in the past. Industry in general has far fewer qualms today about junking things when they have reached their economic life's end even if still not past the bailing wire and solder point. Of course, the automakers, faced with a brutal infighting, are timing tooling life for shorter periods than ever before—and the consumer benefits from the battle for sales points. One example: engine designs that three years ago replaced blocks in use for 20 years are now themselves being hypoed to the limit, or have bitten the dust in favor of V-styled and souped-up designs for '55.

Mining faces neither the same problems, nor hires the same feature demanding sales and advertising managers as the auto industry, but it too could afford a snide look at some of its plant. At least one steel company has taken advantage of the tremendous expansion in steel making capacity and recent cutbacks in production to slice museum pieces from its plant roster. Reportedly management wants to get into fighting trim, with top efficiency and shiny new equipment as its hole card for the competitive struggles ahead. It looks as if "good enough for grandpa" may not be good enough for the cost accountant. For those interested in economic aspects of replacement of equipment further comment may be found in *Company Procedure Manual on Equipment Analysis* reviewed in Books, MINING ENGINEERING, March 1954, and *Realistic Depreciation Policy*, reviewed in August 1954.

CASE HISTORY: *Company Loyalty.* In "The Strange Case of the Round Manhole Covers," Thomas D. Jolly, vice president in charge of engineering and purchases for the Aluminum Co. of America, relates some of the success of the American Standards Assn., and details the spirit of cooperation by which its standards are developed and put to use. All is not standardized in the standards field, however, and we quote:

"Back in 1941 a half-dozen groups sponsored the standardization of manhole covers—the telephone group, the American Foundrymen's Association, the ASCE, the Gray Iron Foundrymen, and the Department of Commerce. Now a manhole cover is a simple piece of industrial equipment. It would seem obvious that if experts got together and worked out a national standard for manhole covers and frames, everyone would adopt it.

"Two years ago I heard a report by a man who had looked into this matter. He found that Annapolis had a manhole standard all its own. It is understandable, therefore that West Point should have its own standard . . . So did the Philadelphia Navy Yard, etc. . . . *One foundryman stated that he had to carry 134 patterns for manhole covers. He said he could reduce his price 30 percent if everyone would use the American Standard.*

"After I heard that report, I went back home and asked our boys if we had adopted the American Standard. They said yes, in every plant except New Kensington. I asked them, 'What's the matter with New Kensington—why can't they use the same thing everyone else uses?' So they brought me the drawing of the manhole covers used there.

"Now that's where I started in with the Aluminum Company years ago—in New Kensington. And I had forgotten all about this, but the drawing said: 'Designed by Jolly, Drawn by Jolly, Traced by Jolly.' Here you will recognize a little of that old company loyalty. The boys weren't going to let me down by using an American Standard over one designed by Jolly. I swear I didn't know then how to design a proper manhole frame and cover. I still don't know."

R. A. Beals

How to handle more material per dollar—YEAR AROUND

THIS Caterpillar No. 6 Shovel has no chance to loaf. It's shown here cutting down a bank of dirt and loading it for road-building fill at Scott County Stone Co., Inc., Scottsburg, Indiana. In addition, it stockpiles and loads crushed rock—keeping busy the year around, no matter what the weather or the ground conditions.

Many owners of No. 6 Shovels also use them for stripping and loading overburden, grading, excavating and cleaning up. Underground, its low over-all height, freedom from overhead clutter, and turning ability enable the No. 6 to put out plenty of work in tight places. With its long bucket reach, the No. 6 Shovel easily loads high-sided hauling units.

One reason for the high work capacity of the CAT* No. 6 Shovel is its carefully engineered balance. Weight distribution, horsepower and bucket capacity are matched so that with capacity loads the tracks are on the ground providing traction from sprockets to front idlers. Another reason: the two-yard bucket tips back 35 degrees in the first few feet of upward travel after loading, so it retains a heaping load of even loose materials, and dumps *clean*.

Bucket controls are well-placed and designed for easy, accurate operation. Ralph B. McNeely, operator of the shovel in the picture, says, "I can do a big day's work with little effort. This machine is powerful, easy to handle, and has good visibility at all times." This fast and easy operation cuts costs. Further savings result from the ability of the rugged Cat Diesel Engine to deliver full and *foul-free* power for only pennies per hour on inexpensive No. 2 furnace oil, thanks to its exclusive, Caterpillar-built fuel injection system.

Your Caterpillar Dealer will demonstrate *on the job* the shovel that will do the most work for *you* at lowest cost. See him today. And count on him whenever you need skilled service and genuine Caterpillar parts.

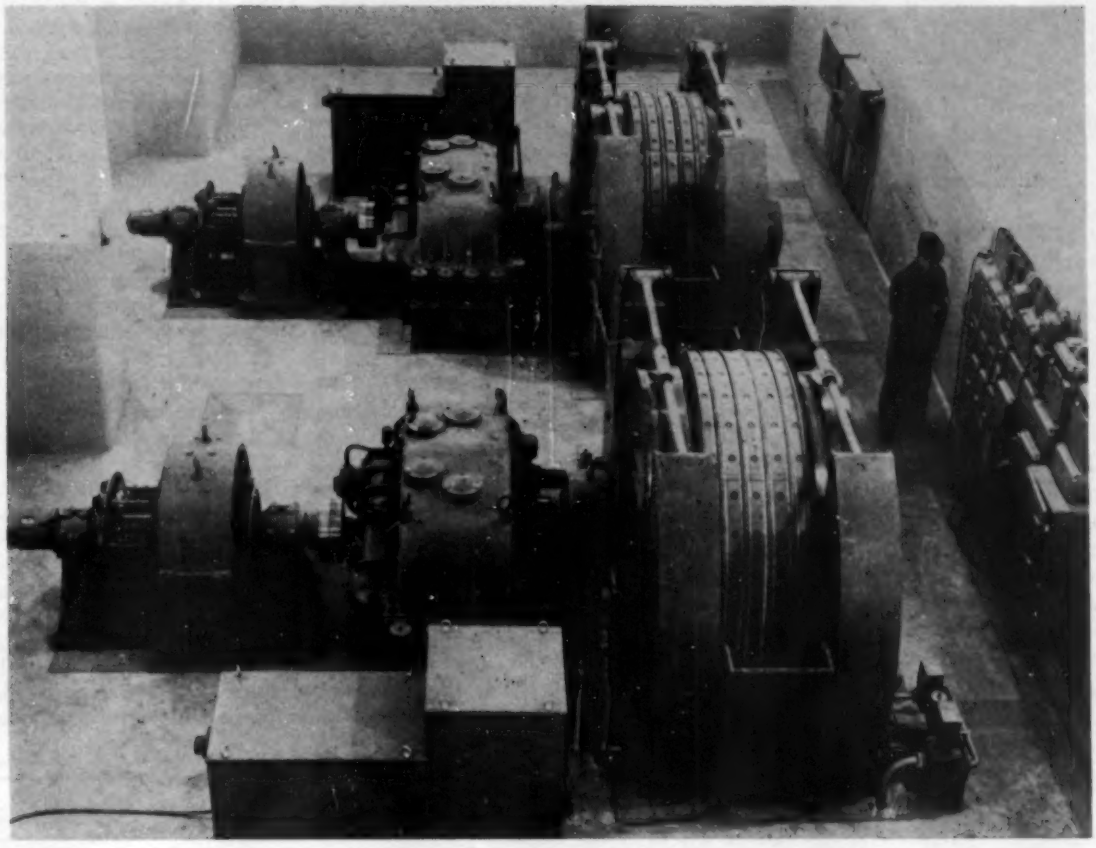
Caterpillar Tractor Co., Peoria, Ill., U.S.A.

CATERPILLAR*

*Both Cat and Caterpillar are registered trademarks—®

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Friction Drive Mine Hoists—



Recent Installations and Design Considerations

by E. P. Pfleider, E. G. Malmlow, and F. Landau

Friction drive hoists, long popular on the Continent, are now being installed in the U. S. and Canada by the Swedish firm of ASEA. Invented by C. F. Koepe and used first in 1877, the principle is the same as that in elevator installations throughout the world. Inherent advantages of this system of hoisting were not fully developed until the recent introduction of the multiple-rope principle and design of concrete tower installations. Operators have a choice of independent operation of single skips and cages using counterweights, or use of skips or cages in balance. Also, hoisting control may be automatic, push button, or manual.

E. P. PFLEIDER is Head, Dept. of Mineral Engineering, School of Mines & Metallurgy, University of Minnesota, Minneapolis, Minn.; E. G. MALMLOW is President, Aros Electric Inc., New York and Electrical Engineer, ASEA, Västeras, Sweden; FRANZ LANDAU is Electrical Engineer and Manager, Mine Hoist Dept., ASEA, Västeras, Sweden.

FRICTION drive mine hoists have been widely used in European installations and are now receiving close attention in the U. S. and Canada. The first U. S. installation, scheduled for operation in 1955, has been designed for the Cleveland-Cliffs Iron Co. in Michigan, by the firm ASEA of Västeras, Sweden. In Canada, ASEA is building two hoists for Falconbridge Nickel Co. at the Sudbury, Ont., plant and another is underway for Algoma Ore Co.

ASEA officials are currently working with American engineers on the design of other friction drive hoists, together with integral concrete headframes for them. Preparation of a safety code covering use of these hoists has been studied by the Ontario Dept. of Mines, and the tentative code developed by E. S. Little and C. M. Barrett of that department is presented on page 39.

Friction drive hoists, also known as Koepe hoists after their inventor, Carl Friedrich Koepe, have proven increasingly popular in Europe since the first installation in Germany in 1877. Most of the shafts in Germany, Belgium, and the Netherlands are equipped with friction drive hoists, and few if any drum hoists have been installed in these countries for years. Britain is also reported to be converting rapidly to the friction hoist, with 12 being placed on order in 1953.[1] The ASEA engineers in Sweden have added many technical advances to the design of friction drive equipment during recent years, particularly in its adaption to completely automatic operation. All principal hoisting installations underway in Scandinavia, highlighted by development of underground operations at the immense Kiruna iron ore deposits, are of friction drive design. The Kiruna plant which features nine shafts in line to raise 4600 tons of ore per hr is to have the hoisting equipment mounted directly over the top of the shaft in a tower type headframe of reinforced concrete construction. Thus, there is a marked similarity to a typical elevator installation in an office building or factory.

Push-Button Operation for New Hoists

Most of the friction drive hoists in operation are in northern Europe, but an increasing number of units are being ordered for mines in the U. S., Canada, Britain, and South Africa. Table I presents highlights of some of the Koepe type hoists recently delivered or on order from one manufacturer, ASEA of Sweden.

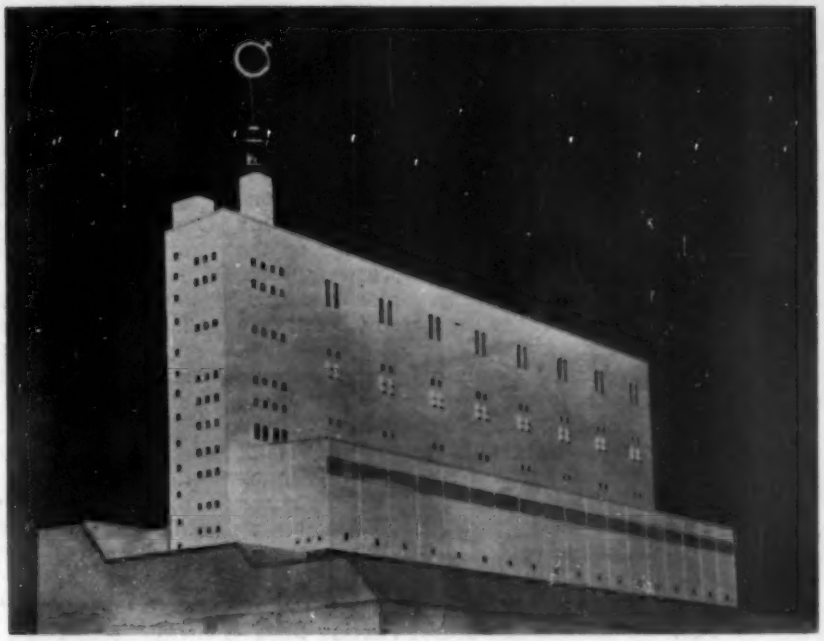
A more detailed study of two hoist installations for U. S. mines is shown in Table II. The multiple-level units are being built for the Cliffs Shaft mine of Cleveland-Cliffs Iron Co. at Ishpeming, Mich. Lack of sufficient surface area for a conventional hoisthouse made the tower type friction drive de-

Table I. Basic Data on Some Recent Friction Drive Hoists

Location	Year of Delivery	Hoists No.	Hoists Type	Pulley Diam, in.	Ropes No.	Ropes Diam, in.	Winding Distance (max), ft	Hoisting* Speed (max), fpm	Weight of Load lb	Weight of Skip lb	Weight of Cage lb	Weight of Balance, lb
Sandvikens Jernverks AB, Sandviken	1945	1	1 cage	71	2	¾	1900	1000	1900	—	4000	5300
Sandvikens Jernverks AB, Sandviken	1945	1	1 skip	126	2	1¼	1900	1000/600	9900	15400	—	20000
Luossavaara-Kiirunavaara AB, Kiruna	1948	2	1 cage	79	2	1	660	800	9900	—	7300	11500
Luossavaara-Kiirunavaara AB, Kiruna	1952	2	1 skip	99	4	1⅛	1500	2200/1100	33000	24000	—	41000
Luossavaara-Kiirunavaara AB, Kiruna	1954	8	1 skip	128	4	1⅜	1500	2200/1100	44000	35000	—	57000
Luossavaara-Kiirunavaara AB, Kiruna	1953	3	1 cage	95	4	1⅛	1500	1000	19000	—	14300	21000
Bolidens Gruv AB, Boliden	1953	1	2 skips	89	2	1⅛	3300	2000/1200	8800	7000	—	—
Bolidens Gruv AB, Boliden	1953	1	1 cage	77	2	⅞	3300	1200	7700	—	5300	9100
Trafik AB Grangesberg-Oxelosund	1954	1	1 cage	49	3	⅝	330	400	4900	—	2600	5100
Outokumpu Oy, Outokumpu, Finland	1954	1	2 skips	118	2	1¼	1300	1400	12000	13000	—	—
Outokumpu Oy, Outokumpu, Finland	1954	1	2 cages	118	2	1¼	1300	1400	12000	—	13000	—
Cleveland-Cliffs Iron Co., Ishpeming	1954	1	1 cage	89	4	1	3940	2000	15000	—	13000	20500
Cleveland-Cliffs Iron Co., Ishpeming	1954	2	1 skip	118	4	1⅛	3940	2000	30000	20000	—	35000
Stora Kopparbergs Bergslags AB, Falun	1955	1	2 skips	83	4	⅞	3300	3200/1600	13000	12000	—	—
Stora Kopparbergs Bergslags AB, Falun	1955	1	1 cage	79	3	⅞	3300	3000/1600	5500	—	5500	8300
Falconbridge Nickel Mines Ltd, Ontario	1955	1	2 skips	118	4	1¼	4200	2240	17000	19000	—	—
Falconbridge Nickel Mines Ltd, Ontario	1955	1	1 cage	118	4	1⅛	4200	2040	13000	—	16000	22500
AB Vieille Montagne, Ammeberg	1955	1	2 skips	53	4	⅝	3300	1200/900	7700	10000	—	—
Algoma Ore Properties Ltd, Ontario	1955	1	1 skip 1 cage	89	4	1	4000	1500	13500	12000	12000	—
New Consolidated Gold Fields Ltd.	1956	1	1 cage	209	2	1¾	5500	3000	6000	—	11700	14700

Electrical system
W-L = Ward-Leonard
3-ph = three-phase induction motor

* When two figures are given, the lower speed refers to the motor rating listed on facing page.



This multiple-shaft layout with tower type friction drive hoists at the Kiruna iron mines in Sweden features nine shafts in line to raise 4600 tph. Opposite page shows another modern Swedish headframe design with tower installation of friction drive hoist and gravity flow of ore through crushing plant.

sign particularly attractive. A cutaway view through the headframe, shaft, and underground crushing and loading stations is shown on page 29.

At CCI ore will be crushed underground to 4-in. and hoisted in 15-ton bottom dump skips through *push-button* control. Each skip is operated with a 35,000-lb counterweight, permitting completely independent operation. The 9 ft 10-in. diam pulley gives a D/d ratio of 105, using four 1⅛-in. hoisting ropes. The low inertia (WR^2) of 1.26 million lb-ft² for all rotating parts represents approximately 450,000 for each pulley, 8000 for each motor, and 172,000 for each group of four deflection sheaves. This figure of 1.26 million compares with a figure of 5.35 million lb-ft² for a somewhat similar drum hoist. Calculated root mean square (rms) horsepower for the motors is 1200 each, or 2400 hp total, whereas a comparative drum hoist for the same job would require at least 2700 hp according to conventional rms calculations.

The single-level balanced hoisting unit of 10-ton capacity at 1895-ft depth, detailed in Table II, was designed for a new potash development in the Carlsbad area. It is important to note that the equivalent of 11,000 lb had to be added to the normal weight of each bottom dump skip in order to decrease the rope tension ratio $(T_1/T_2)_{max}$ to 1.55, a figure assuring sufficient safety against slip at the acceleration of 1.6 ft/sec.² In this case the extra weighting of the skips tends to partially nullify the usual advantages of the friction drive over drum hoisting: namely that of lower inertia, 960,000 vs 2.4 million lb-ft², and of balanced rope weight. It should be pointed out that either a lighter skip load than 10 tons or a greater depth than 1895 ft would permit a decrease in the skip weighting. The reverse is also true, i.e., heavier skip load or lesser depth would demand heavier weighting.

Irrespective of the question of weighting required in this installation, the calculated rms horsepower for the friction drive unit is but 900, against 1000 hp for the drum hoist. The design calls for a tower type installation having an 88-in. pulley and four 1-in. ropes with fully automatic operation. Hoisting speed of 1260 fpm is about 0.38 v_o, where $v_o = \sqrt{as}$ or $v_o = \sqrt{1.6 \times 1895} = 3300$ fpm. Drum hoists for similar conditions have almost identical accelerations and speeds, being based on customer approval.

The service hoist, also friction drive, is rated for 15-ton equipment load on a 6500-lb cage, with 30,500 lb of counterweight and four ⅞-in. ropes on a 70-in. pulley. Static factors of safety for the ropes are 6.1 for equipment loading and 10 for personnel. Hoisting speed is set at 800 fpm, and acceleration at 1.33 ft/sec² giving the hoist motor 165 rms hp, calculated.

Elect. System	Winding Motor hp	rpm	V	Cycles	Mannner of Operation	Name of Shaft
W-L	50	1000	440	DC	PB9	Bodas
W-L	135	750	440	DC	PB3	Bodas
W-L	185	730	440	DC	PB8	Luossavaara
W-L	680	750	510	DC	PB3	Shaftarea 1
W-L	1150	750	600	DC	PB3	Central shaft
W-L	410	800	440	DC	PB8	S2-4
W-L	435	750	440	DC	PB2	Renstrom
W-L	220	750	220	DC	RM	Renstrom
W-L	30	1080	230	DC	PB2	Grangesberg
3-ph	670	730	3000	50	PB2	Keratti
3-ph	250	730	380	50	PB2	Keratti
W-L	1500	600	525	DC	PB12	"C"-shaft
W-L	1500	600	525	DC	PB6	"C"-shaft
3-ph	900	730	380	50	PB2	Bergslags shaft
W-L	380	750	440	DC	PB12	Bergslags shaft
W-L	1500	600	600	DC	PB2	No. 1 Fecunis
W-L	665	750	600	DC	PB15	No. 1 Fecunis
3-ph	250	730	380	50	M	Nygruvan
W-L	800	750	600	DC	PB12	
W-L	1100	600	600	DC	M	West Driefontein

Manner of operation
M = manual operation
RM = remote manual operation
PBx = push-button operation from x levels

Hoist Design Analysis

Friction drive hoists may be placed at ground level in a conventional manner or used in the *tower* design where the hoist is in the headframe directly over the shaft compartments. It is possible to have single or multiple rope arrangements connected either to both skips for balanced hoisting from one level or with one end connected to the conveyance and the other to a counterweight for multilevel hoisting. The diagrams make these features clear and show that the problem of fleet angle is completely avoided.

All friction drive hoists have a balancing tail rope which usually has the same weight per unit length as the hoist ropes. Carrying only its own weight, the resulting stresses on the tail rope are very small compared with rope strength. Service life is much longer than for hoist rope, reaching seven to ten years under fair operating conditions. Even though the hoist be of multirope design, the tail rope may be a single flat type. A recent trend for deeper shafts is use of two flat ropes of identical construction for ease of handling during installation. No guide pulleys are needed at the bottom of the shaft where the tail rope turns.

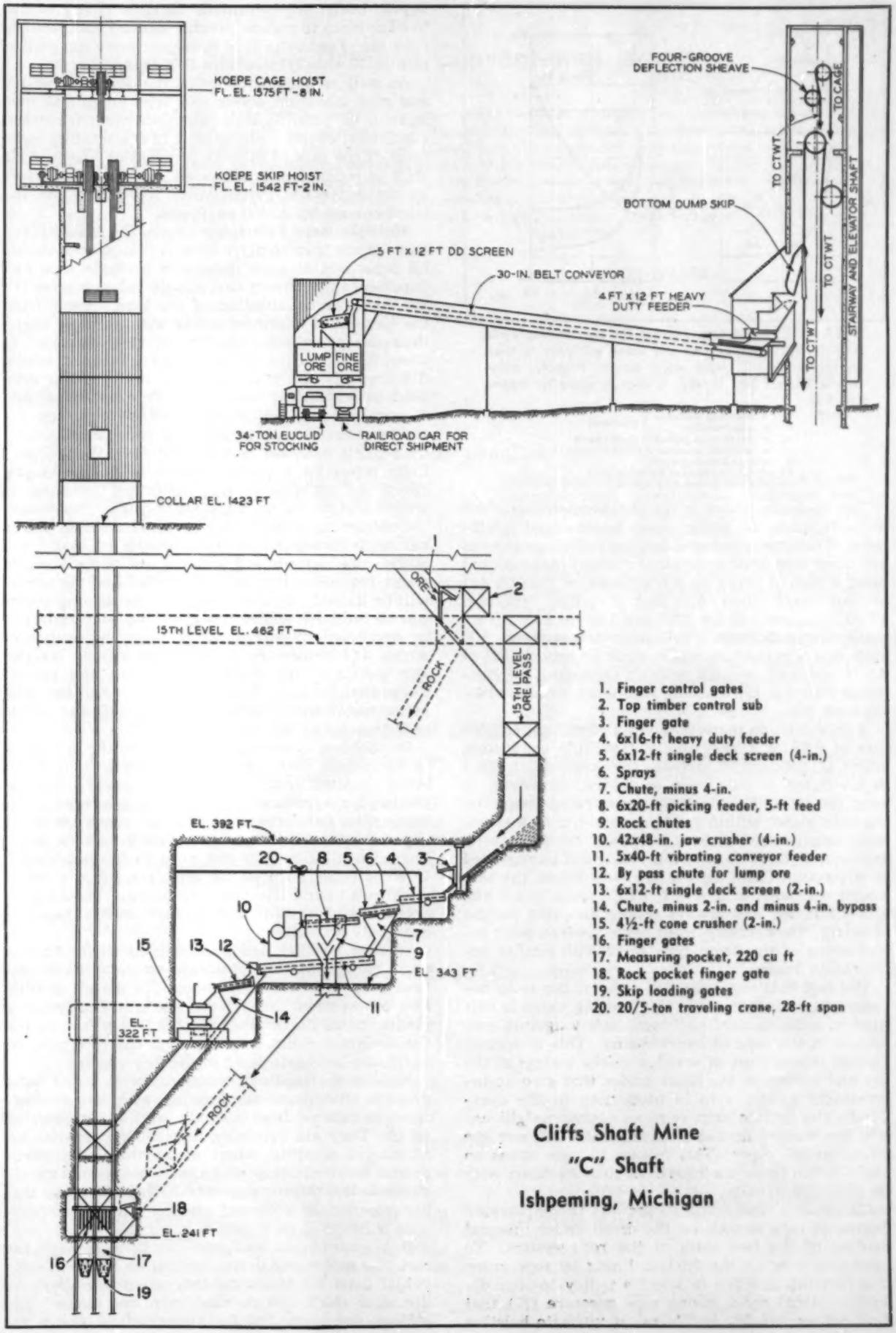
Use of a tail rope to balance the hoist ropes reduces peak power demand to such a low value that flywheels are seldom considered or used. Surprisingly, total rope requirements with a ground installation for hoisting in a single-level operation with skips in balance are less for friction drive than for a drum hoist, being twice the depth of shaft for the former, and twice shaft depth *plus* extra wraps on the drums for the latter. This advantage is more marked if advantage is taken of rope savings possible in the tower type installation.

Friction Drive Principle: Landau[2] and others have written detailed discussions of the principle of friction drive hoists. Briefly these principles include the relation between rope tensions, acceleration, and slip; and the effect of specific rope pressure and bending stresses on diameters of pulley and rope.

Table II. Comparison Study: Friction Drive vs Conventional Drum Hoists for Two U. S. Mines

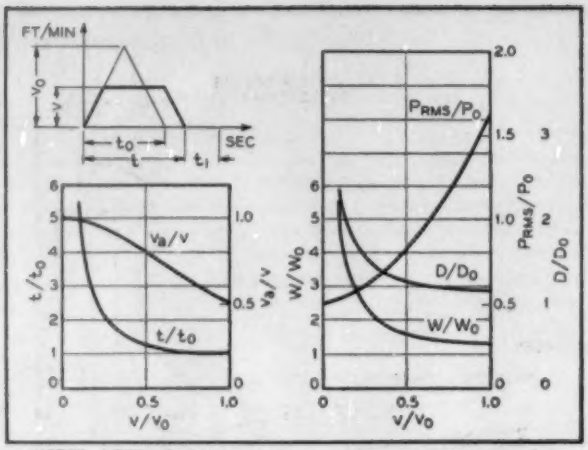
	MULTIPLE-LEVEL INSTALLATION		SINGLE-LEVEL BALANCED HOISTING	
	Two Friction Drives in Headframe	Conventional Double Drum	Friction Drive in Headframe	Conventional Single Drum
Hoist Type and Design	Individual Motor Drives	Two Motor Drive	Ward-Leonard m-g Set	Ward-Leonard m-g Set
Depth of Shaft—ultimate	3,940	3,940	1,895	1,895
Weight of Ore	30,000	30,000	20,000	20,000
Skip Weight	20,000	20,000	13,000	13,000
Counterweight	35,000**	—	11,000*	—
Rope: Skip				
No. & Size (d), in.	Four—1⅛	One—1⅜	Four—1	One—1¾
Total Length, ft	8000 for 2 skips	8,500	2,000′±	4,500′±
Weight of rope, downside only, lb	32,500	22,500	12,500	9,600
Rope: Tail				
No. & Size, in.	Flat Belt—⅜x7	—	Flat Belt	—
Length, ft	8000 for 2 skips	—	2,000±	—
Weight, lb	32,500	—	12,500	—
Drums or Pulleys	2 pulleys	2 drums	1 pulley	drum
Diameter (D)—in.	118	144 (8 ft face)	88	132
Ratio D/d	105	77	88	76
Hoisting Speed, fpm	2,000	2,000	1,260	1,260
Acceleration—ft/sec²	2.22	2.22	1.6	1.6
Cycle Time, sec				
Acceleration	15	15	13	13
Constant Speed	104	104	77	77
Deceleration	15	15	13	13
Rest	30	30	15	15
Total	164	164	118	118
Rope Stresses, Static				
Loaded Side T_1	82,500	72,500	56,500	42,600
Empty Side T_2	67,500	20,000	36,500	13,000
T_1/T_2 Dynamic	1.40	—	1.87	—
T_1/T_2 Static	1.22	—	1.55	—
Rope Pressure in Grooves, psi	283	—	265	—
Safety Factor, Static	5.15	3.9	6	5.9
Hoisting, Capacity				
Trips/Hr (no delays)	22	22	30.5	30.5
Tons per Hr	330	330	305	305
Weight of Mechanical Parts, lb	160,000	—	65,000	230,000
Inertia of Rotating Parts, psi	1,260,000	5,365,000	960,000	2,400,000
Dc Hoist Motor Calculated rms	1200 each or 2400 total	2700 total	900	(2-500) 1000

* Built into each skip to obtain sufficient weight for a T_1/T_2 (Static) ratio of 1.55.
** Counterweight for each skip equals one half weight of ore plus weight of skip.



1. Finger control gates
2. Top timber control sub
3. Finger gate
4. 6x16-ft heavy duty feeder
5. 6x12-ft single deck screen (4-in.)
6. Sprays
7. Chute, minus 4-in.
8. 6x20-ft picking feeder, 5-ft feed
9. Rock chutes
10. 42x48-in. jaw crusher (4-in.)
11. 5x40-ft vibrating conveyor feeder
12. By pass chute for lump ore
13. 6x12-ft single deck screen (2-in.)
14. Chute, minus 2-in. and minus 4-in. bypass
15. 4½-ft cone crusher (2-in.)
16. Finger gates
17. Measuring pocket, 220 cu ft
18. Rock pocket finger gate
19. Skip loading gates
20. 20/5-ton traveling crane, 28-ft span

Cliffs Shaft Mine
"C" Shaft
Ishpeming, Michigan



UPPER LEFT: Speed-time diagram for one hoisting cycle. LOWER LEFT: Hoisting time and speed efficiency vs hoisting speeds. RIGHT: Hoist motor output, Prms/Po; pulley diam D/Do; net load W/Wo; vs hoisting speed for loading time 0.3t_o.

With: s = hoisting distance, a = acceleration } constant
V_o = maximum possible rope speed
t_o = shortest possible hoisting time
V = any hoisting speed
t = corresponding hoisting time
V_a = average hoisting speed

The diagram above gives the acceleration limit as a function of static rope tension and coefficient of friction when $\alpha = 180°$ or π. Pulley grooves are lined with leather or other friction material and hoist design is based on a coefficient of friction (μ) of not more than 0.2 and a pulley constant $(T_1/T_2)_{dynamic}$ of 1.87 for 180° and 2.23 for 230°. Normally the maximum $(T_1/T_2)_{static}$ is placed at 1.5, such that a maximum acceleration or retardation of 3.5 ft/sec^2 may be used without exceeding the condition stated in Eq. 1 above, and hence without risking rope slip.

A good friction material gives a coefficient of friction of 0.25 or higher under favorable conditions, which is sufficient to increase the acceleration limit to 5.5 ft/sec^2 if this were necessary. However, to keep the ratio of starting torque to rated torque on the hoist motor within good practical limits, a *maximum acceleration of about 2.8 ft/sec^2 for deep shafts and up to 3 ft/sec^2 for shallow shafts can be regarded as adequate.* These figures are well below the safe design constants of $\mu = 0.2$, $(T_1/T_2)_{static} = 1.5$ and $a = 3.5$ ft/sec^2 and always retains an extra margin of safety. Incidentally, most large modern hoist installations of the drum type work with similar acceleration figures.

The fact that rope slip will occur if the ratio between rope loads exceeds the limiting value is utilized in order to gain additional safety against rope failure in the case of overwinding. This is accomplished through use of wooden safety wedges at the top and bottom of the shaft guides that give an increasingly tighter grip in proportion to the overwind. The bottom skip, cage, or counterweight enters the wedges first and subsequently releases the stress on the ropes. This release in rope stress on one side can cause the rope to slip on the drum with no resulting damage.

Continuous rope creep occurs due to the varying degree of rope stretch on the drum under unequal loading of the two sides of the rope system. To minimize wear on the friction lining by rope creep it is Swedish practice to select a pulley-to-rope diameter (D/d) ratio, giving rope pressure (K) that does not exceed 265 to 275 psi at ultimate hoisting depth. Under any conditions the ratio (D/d) is held to 80 or more to reduce bending stresses and increase rope life. For shafts 2000 ft deep or more the limitation on K usually results in D/d being over 80.

As well as being a factor in the design of pulley and rope diameter, continuous rope creep and rope stretch, or possible rope slip under extraordinary conditions, causes a slight shift in the spotting locations of the skip or cage at the various levels. This shift is continuously corrected each hoisting cycle by an automatic synchronizer developed for the friction hoist by ASEA engineers.

Multiple-Rope Principles: One of the chief advantages of the friction drive hoist is that several parallel ropes can be used instead of a single rope and experience has shown that simple balance arms are adequate for equalization of the load. Apart from the element of improved safety with multiple ropes, their use permits a reduction in rope diameter to about 0.5 to 0.6d (or $d/\sqrt{4}$) for a 4-rope hoist, where d represents the rope diameter for a single rope hoist under similar conditions. This factor permits a corresponding reduction in drum or pulley diameter since the 80 to 100 D/d ratio usually controls. This decrease in diameter, even though partially offset by a small increase in pulley length, effects an appreciable and important lowering of weight and inertia as compared to single rope design.

Considering a multiple-rope system whose pulley has approximately half the diameter of that for a single-rope system and yielding the same hoisting speed, the pulley rpm will be doubled and the torque will be halved. As a consequence the driving motor can be built for higher speed, or the gear ratio can be decreased if gear drive is employed, either of which will reduce the physical dimensions, weight, and inertia of the driving equipment and pulley. These changes make it practicable to install the hoist in the headframe directly over the shaft and eliminate the cost of the hoisthouse.

In addition to savings in structure, the reduction in equipment size, weight, and inertia makes for lower capital cost, lower peak power demand, smaller hoist motor ratings, and more advantageous dimensions for the brakes. Further, ropes are never exposed to the weather, and there is less tendency toward oscillation with the hoist in the headframe. In some cases, such as the Michigan installation, it is difficult to find a suitable site around the shaft for hoisthouse location and tower design becomes especially attractive.

Modern Swedish headframes designed for friction drive hoisting are of reinforced concrete, have vertical sides, and are tall enough to permit gravity flow of ore down through storage bins and crushing plants. Some headframes are 220 to 240 ft high, but the designers claim economy over use of conveyors to lift the ore again later in the flowscheme.

Multilevel Hoisting: Friction drive hoists offer greatest advantages for hoisting with two conveyances in balance from a single level at considerable depth. They are becoming increasingly popular for multilevel hoisting when employing independent drums for each skip or cage. The counterweight balances the skip or cage and half the load, so that the same torque is needed whether a loaded conveyance is lifted or an empty is lowered.

It is possible in multilevel hoisting to save the cost of a motor and drive mechanism for each individual hoist by mounting two adjacent pulleys on the same shaft and driving from one motor. The pulleys are connected by a mechanical clutch for

Friction Drive vs Conventional Hoists

The recent introduction of the multiple-rope principle, together with the design of concrete tower installations, the choice of independent operation of single skips and cages by using counterweights, and the development of fully automatic operation have highlighted the inherent advantages of the friction drive (Koepe) hoist. The trend toward larger scale production from greater depths, using central plants and the improved bottom dump skips, has accentuated these advantages. The friction drive hoist should be considered for any moderate to large scale hoisting installation serving a vertical shaft having a depth sufficient to develop a $(T_e/T_s)_{static}$ rope tension ratio of less than 1.5 by weighting or counterweighting.

Comparative advantages and disadvantages of the friction drive hoist with respect to the conventional drum hoist are summarized below:

ADVANTAGES	DISADVANTAGES
Safety	
1. Several parallel ropes are used, instead of a single rope.	1. Rope cannot be lubricated with grease for protection against corrosion, although it can be galvanized or covered with a resinous lacquer.
2. Safety wedges on shaft guides assure rope slip and prevent overwind.	
Rope Wear and Cost	
1. Wear is less due to elimination of fleet angle, absence of S-bends, and elimination of cross-overs in multilayer practice.	1. More rope is required, tail rope included, for multiple level installations, although tail ropes give very long service life. Rope requirements are approximately the same for single level balanced hoisting.
	2. Rope changes are more difficult; also double the number to change for independent operation of skips.
	3. Ropes must be replaced if shaft is deepened.
	4. Rope ends cannot be cut off for inspection for single level-balanced hoisting installations.
Size and Cost of Hoisting Unit	
1. Smaller diameter and narrow width of pulley give low unit weights and inertia.	1. Space must be provided in shaft for counterweight travel if a multilevel operation.
2. Compact size and low weight permits installation in headframe above shaft with gravity flow through ore preparation plant.	2. Additional cost for counterweights.
3. Simple design of pulley can be standardized since independent of depth of shaft.	
4. Above factors result in lower capital and operating cost.	
Power Demands and Consumption	
1. These are lower due to balancing weight of tail rope and the decreased inertia of rotating parts.	— none noted —
2. Peak demands of individual conveyances in multilevel operation can be offset automatically by electric control.	
Flexibility	
1. Friction drive pulley can be used as single drum, single rope hoist for initial shaft sinking.	1. The shaft must be kept some 30 ft deeper than otherwise required in order to prevent damage to tail rope by blasting at start of shaft deepening operations.
2. Independent operation of single hoists, with counterweights, permits hoisting from different levels concurrently or in one compartment only if the other is tied up with repairs or sinking operations.	

Friction Drive Principle:

Basic Equations

1. *The relation between rope tensions, acceleration, and slip.*
No slip occurs when

$$(T_1/T_2)_{dynamic} \leqq e^{\mu\alpha} \qquad [1]$$

where
T_1 = tension on the loaded side of the rope at the point where it enters or leaves the pulley.
T_2 = tension on the unloaded side of the rope at the point where it enters or leaves the pulley.
μ = coefficient of friction of the rope on the pulley.
α = angle of pulley covered by rope in radians.
e = 2.718

The rope tensions vary with the rate of acceleration, *a*, or retardation, *r*, the following relation existing between static and dynamic rope tensions:

$$(T_1/T_2)_{dynamic} = (T_1/T_2)_{static}\left[\frac{g+a}{g-a}\right] \qquad [2]$$

The diagram gives the acceleration limit as a function of static rope tensions and coefficient of friction when $\alpha = 180°$ or π.

2. *The specific rope pressure and/or bending stresses determine the ratio of pulley and rope diameters, D/d.*

$$K = \frac{(T_1 + T_2)_{static}}{D\,d\,z} \qquad [3]$$

and

$$D/d \geqq 80 \qquad [4]$$

where
K = specific rope pressure on groove in psi.
D = diameter of pulley, in.
d = diameter of rope, in.
z = number of ropes, if multirope hoist.

3. *Optimum Hoisting Speed*

Referring to the speed-time curve, and assuming that acceleration, *a*, is constant and equal to retardation, *r*, then

$$v_o = \sqrt{as} \qquad [5]$$

$$t_o = 2\sqrt{s/a} \qquad [6]$$

$$t = \frac{v}{a} + \frac{s}{v} \qquad [7]$$

hence $$t/t_o = 0.5\left[\frac{1 + (v/v_o)^2}{v/v_o}\right] \qquad [8]$$

where
s = hoisting distance
v_o = maximum possible rope speed
t_o = corresponding shortest hoisting time
v = hoisting speed
t = corresponding hoisting time.

Diagram relating the effect of varying rope speeds on hoisting time as expressed by Eq. 8, shows dramatically the small decrease in hoisting time resulting from an increase in rope speed above 0.4 to 0.5 v_o. Similarly, the approximate relationships of Net Loads (W/W_o), Rope and Pulley Diameters (D/D_o), and Hoist Motor Output (P_{rm}/P_o) are indicated as Hoist Speed varies (v/v_o).

adjustment to varied level hoisting, much the same as in conventional drum hoists. The drawback to this design, however, is the lack of flexibility and adaptability to automatic control, so that the favored installation calls for individual motor drives for each pulley and compartment. The individual drive then permits completely independent operation and push-button control.

Independent operation of individual conveyances has several advantages:

1) Ore can be hoisted from different levels simultaneously, if and when desired.

2) Production can be continued on a decreased scale even though one skip is out of operation due to difficulty in the shaft, or other causes.

3) Peak demand for power can be decreased by staggering the high demand periods of the individual hoists through automatic relays.

4) The productivity of a second cage in a two cage setup is greatly increased. Time studies have shown that capacity obtained by two cages driven by a common hoist is but 30 pct higher than with single cage.

5) The shifting of level from which hoisting is to be done is carried out by a simple changeover switch, permitting hoisting from the new level without any intermediate delay for readjustment of drum positions, as is the case with clutches on conventional drum hoists.

For the friction drive hoist, then, independent operation of single conveyances allows hoisting from different levels while offering the advantages of flexibility, increased capacity, and particular adaptability to push-button operation.

Optimum Hoisting Speed: There is a most economic rope speed for every hoisting distance. That rope speed in most cases can be attained within a reasonable acceleration time with the rates possible with friction drive and this ability to attain optimum rope speed is of vital consideration in the selection of any hoisting system.

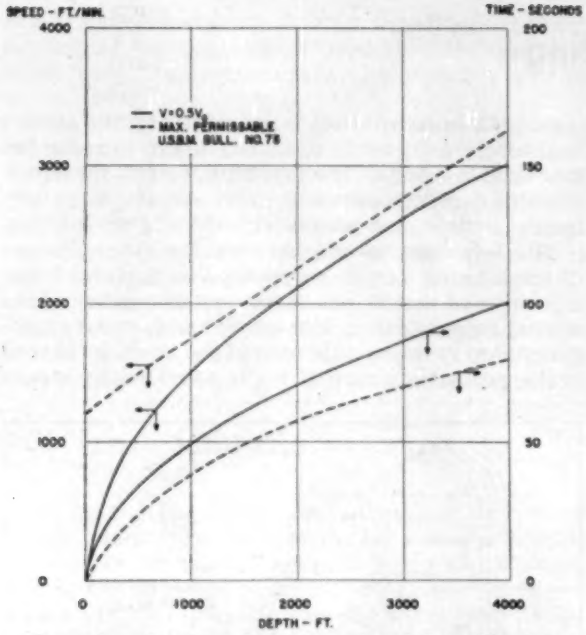
F. Landau has studied the effects of varying rope speed and fixed production requirement on cycle time, net load, diameter of rope and pulley, hoist motor output, and total cost of hoisting unit. The basic equations and relationships he developed are given in the table of equations and shown in the speed-time curves. The relationships in the diagrams highlight these points:

1) The proportionately small decrease in hoisting speed, net load, and rope and pulley diameters resulting from an increase in rope speed above 0.4 to 0.5 v_o.

2) The appreciable rise in hoist power requirement resulting from a corresponding increase in rope speed above 0.4 to 0.5 v_o.

It can therefore be considered that *the economical or optimum hoisting speed is equal to 0.4 to 0.5 of the maximum speed possible (v_o) for a given depth and acceleration rate.*

The summary diagram relates hoisting speeds and time to shaft depths when $v = 0.5\ v_o$ and $a = r = 2.5$ ft/sec.^{2} Velocity and time curves for maximum permissible hoisting speeds and acceleration rates from the U. S. Bureau of Mines Bull. 75[5] *Rules and Regulations for Metal Mines* are given for comparison. Total cycle times for the so-called optimum speeds are 20 to 25 pct greater than comparable figures for maximum permissible conditions, when allowing a 5-sec rest or loading period. Hence the skip load must be greater for a fixed tonnage output, but the hoist motor output would be appreciably less.



Comparison of optimum hoisting speeds and time with maximum permissible speeds cited in USBM Bulletin 75. Optimum speed 0.5 v_{ul} and acceleration 2.5 ft/sec.²

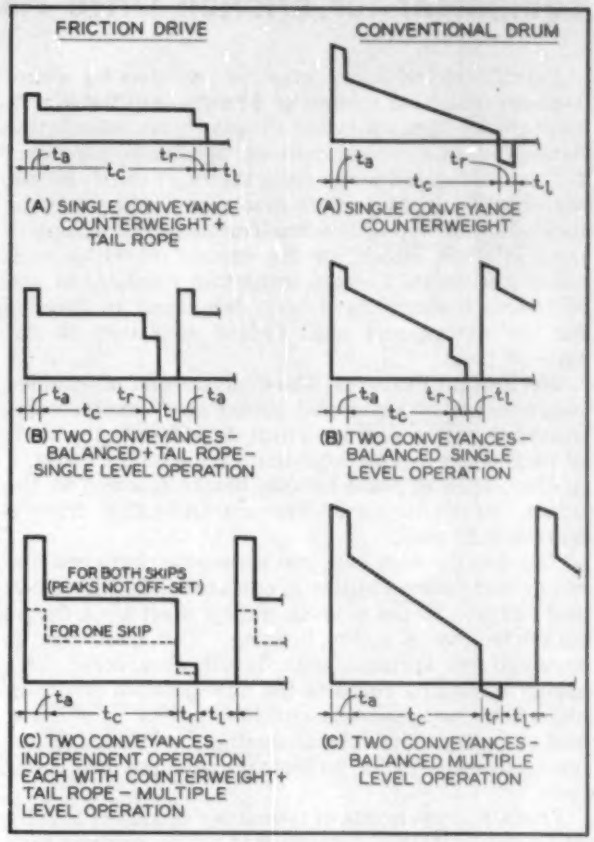
Duty Cycles and Power Requirements: The lower peak power demand of the friction drive hoist is an effect of the balancing tail rope and the lower inertia of all rotating parts. A single cage operation is particularly adaptable to the friction drive, being somewhat similar to a commercial elevator installation. It has considerable advantage over an unbalanced drum hoist insofar as torque and power requirements are concerned.

Single-level operation, with balanced skips or cages, probably provides the most favorable situation for the use of the friction drive. This is especially true if the hoist can be situated in the headframe over the shaft. Counterweights are not required, but it is often necessary in shallow shafts to build extra weight into the skips in order to obtain a satisfactory T_1/T_2 ratio.

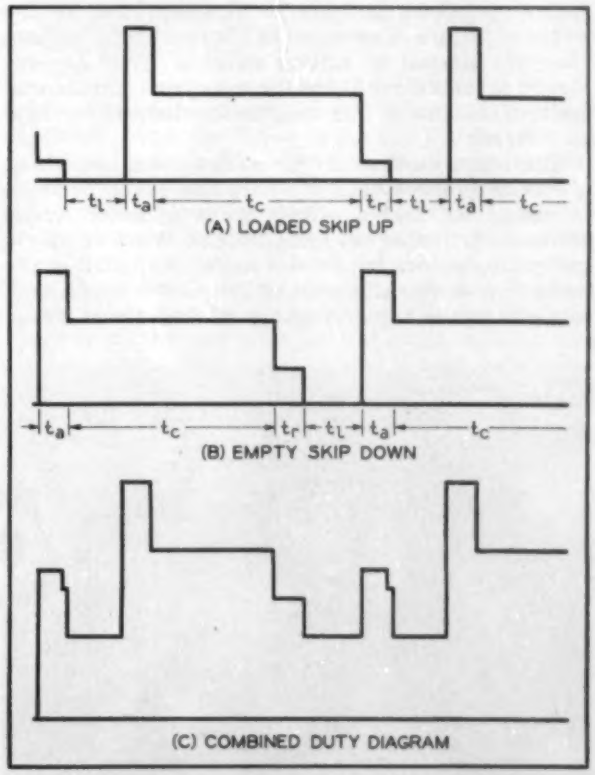
Multilevel operation, with independent hoists for each conveyance, permits the further lowering of peak demands through the automatic offsetting of acceleration peaks. When the two units have their hoisting cycles in sequence and the loaded skip starts up as the empty skip starts down, as in the case with the drum hoist, it is necessary to accelerate all moving parts concurrently. By blocking the acceleration period of the up-coming loaded skips from coinciding with the acceleration period of the second skip, it is possible to effect lower peak demands. This can be done automatically by electric delays, thereby reducing the peak loads to such small values as to eliminate the necessity of using Ilgner sets with flywheels to store the energy needed in conventional hoisting for high peak demand periods. As previously mentioned, this independent operation makes it possible to hoist from different levels concurrently, a possible advantage if a newly opened level has but one skip pocket, or if one compartment of the shaft is temporarily out of commission.

Furthermore, the use of single conveyances with counterweights improves the friction conditions to such a degree as to make this system suitable for hoisting from shallow depths. Here, the ratio T_1/T_2 is reduced by having a counterweight equal to the weight of the conveyance plus half the net load.

Duty Cycle Diagrams


FRICTION DRIVE
CONVENTIONAL DRUM
(A) SINGLE CONVEYANCE COUNTERWEIGHT + TAIL ROPE
(A) SINGLE CONVEYANCE COUNTERWEIGHT
(B) TWO CONVEYANCES - BALANCED + TAIL ROPE - SINGLE LEVEL OPERATION
(B) TWO CONVEYANCES - BALANCED SINGLE LEVEL OPERATION
FOR BOTH SKIPS (PEAKS NOT OFF-SET)
FOR ONE SKIP
(C) TWO CONVEYANCES - INDEPENDENT OPERATION EACH WITH COUNTERWEIGHT + TAIL ROPE - MULTIPLE LEVEL OPERATION
(C) TWO CONVEYANCES - BALANCED MULTIPLE LEVEL OPERATION

Comparative duty diagrams for friction drive and cylindrical drum hoists.



Duty cycle diagram for two independently operated skips having the acceleration peaks offset by automatic delays to avoid compounding of peak loads.

Equipment for Friction Drive Hoisting

Friction drive hoists may be powered by either 3-phase induction motors or dc motors in the Ward-Leonard system. Similar to any hoist installation having Ward-Leonard control, the motor-generator set can be located away from the hoist itself. Hence, the friction drum and its motor and drive may be located at the top of the headframe, with the motor-generator set either on the ground or on a deck below the hoist. Certain important mechanical and electrical features have been developed in Sweden for the design and push-button operation of this type of hoist.

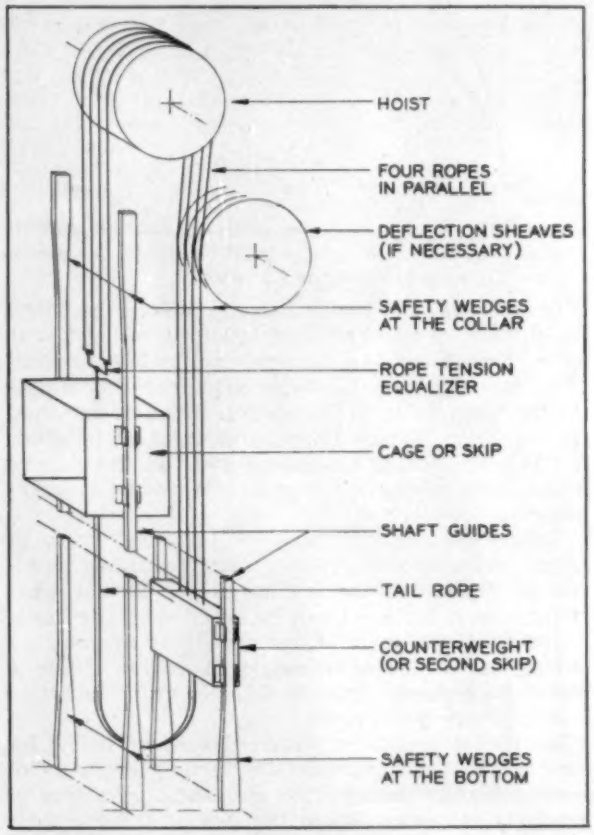
Mechanical Features: The drums are of all-welded construction of plate and rolled steel sections and provided with a cast steel hub shrunk onto the shaft of forged steel. The rope seats are usually made of leather, held in place by oak blocks screwed to the drum. Brake lining of Ferrode and other friction materials is used.

The totally enclosed precision gear between the motor and driving pulley is automatically lubricated and coupled to the driving pulley shaft by a flange supported by a roller bearing. The gear box is mounted on springs, with recoil absorbers. This spring mounting corrects for any possible errors in alignment and smooths out load peaks in starting and stopping, particularly during emergency braking. All bearings for pulley and gear box are roller type.

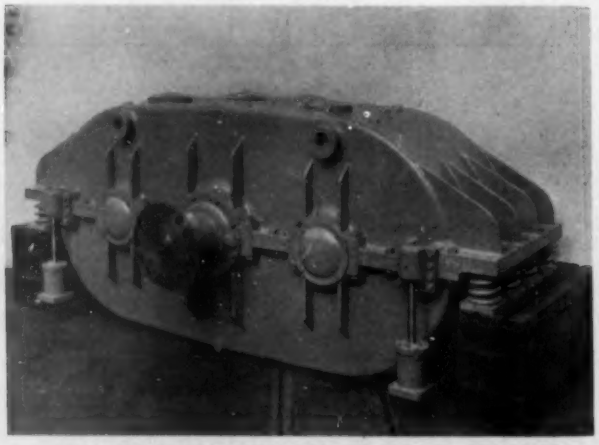
Friction drive hoists of Swedish design are usually equipped with two independent brake systems acting on drums on either side of the pulley, each system combining a service and emergency brake. The brakes are power applied for both service and emergency operation, but are so arranged that in the event of failure of pressure of the operating medium they are applied by falling weights. They are designed to hold three times the maximum unbalanced load or to retard the maximum descending load at 6 ft/sec.[5]

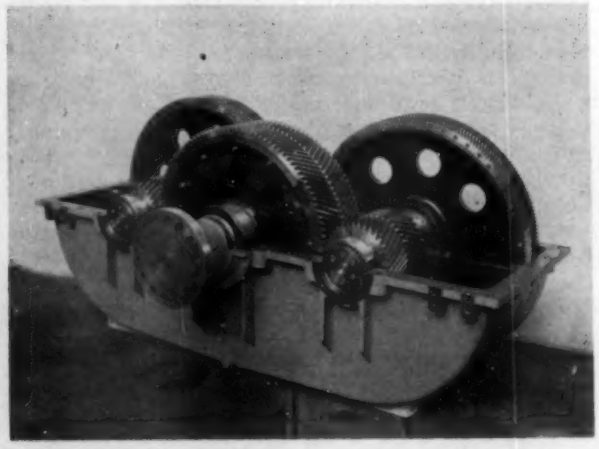
The brake mechanism for each system consists of a service brake cylinder, where the brake pressure is developed, and a safety brake cylinder whose piston supports the dropping weight. When an emergency stop occurs the service brake is applied at the same time as the safety brake cylinder is discharged, but due to the rapid response of the service brake piston the braking effort is developed by the service brake before the air in the safety brake cylinder has had time to escape. The dropping weight, therefore, remains freely suspended. This results in a very quick, smooth and absolutely shock free braking.

The lever mechanism between the two cylinders of the braking system is arranged so that the braking forces of the service brake and emergency brake are not superimposed. For normal stop, or for emergency stop in the middle zone of the shaft, a reduced brake pressure is used. This is provided by means



Diagrammatic sketch shows multiple rope installation of friction drive hoisting facility.





LEFT: Precision gear assembly between motor and driving pulley of hoist, mounted on springs to correct for possible errors in alignment and to smooth out peak loads. RIGHT: Opened case shows construction of gear box.

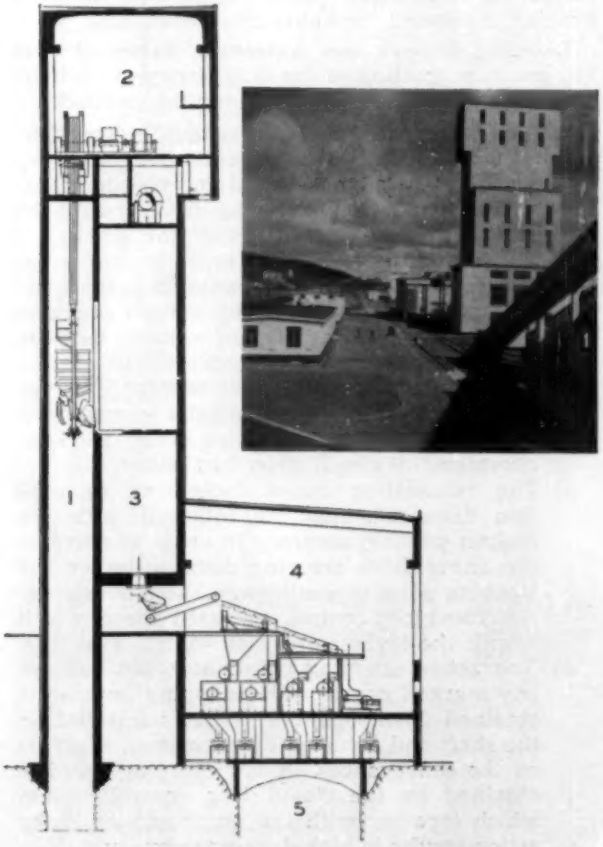
of a reducing valve, which is bypassed near the end position of the conveyance by a solenoid operated valve providing maximum brake pressure in the danger zone.

Ropes: Normally ropes of flattened strand or of Seale construction are used, galvanized where corrosive conditions exist. Galvanized ropes, delivered dry, have a higher friction factor, although this can be achieved also by covering the rope with a special resinous lacquer, which tends to preserve the rope as well. Generally no dressing is used. Rope life is usually at least three years, this being considered a satisfactory period of service even though the rope is still in good condition. Rope safety factors in Sweden for combined ore and man hoists are:

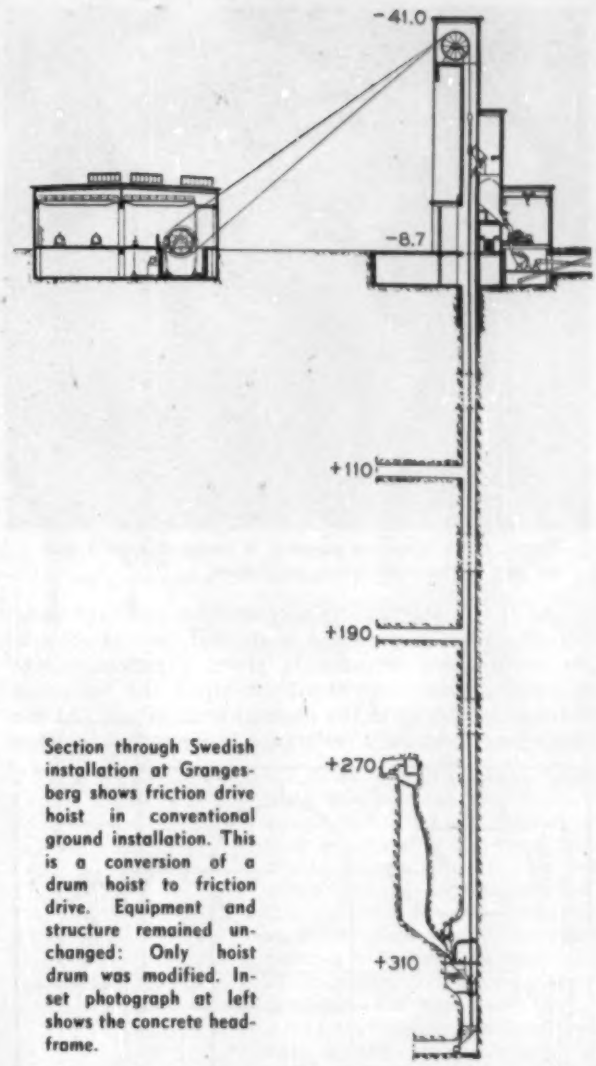
	Men	Ore
Without Safety Dogs	10	7.5
With Safety Dogs	8	6

Most tail ropes are flat and galvanized, but round strand nonrotating ropes of the same size and number as used for hoisting are now in service. Average life is seven to ten years. Timbers are employed across tall rope loops to prevent ropes from twisting, but pulleys and sheaves are not used. An equal number of right-hand and left-hand lay ropes are used to eliminate rope twist and reduce wear on the shaft guides.

Automatic Control: Skip hoists were originally push button operated from the loading station. Since the introduction of underground crushing many of the latest installations are designed for wholly automatic operation, incorporating automatic filling of the measuring pockets and loading of the skips to a predetermined tonnage. Service hoists are either operated remotely by a hoistman at the control panel or push button operated by the passengers from both the cage and the different shaft levels. All ten skip hoists for the iron ore mines at Kiruna in the north of Sweden, two for 16.5 tons and eight for 22 tons net load, are designed as four-rope friction drive hoists with wholly automatic control. These hoists will be working from the first shift on Monday to the last shift on Saturday without any manual attention.



Section through typical reinforced concrete headframe with friction drive hoisting. Numbers: 1—shaft, 2—engine house, 3—crude ore pocket, 4—magnetic separation plant. Inset shows Swedish concrete headframe at Grangesberg.



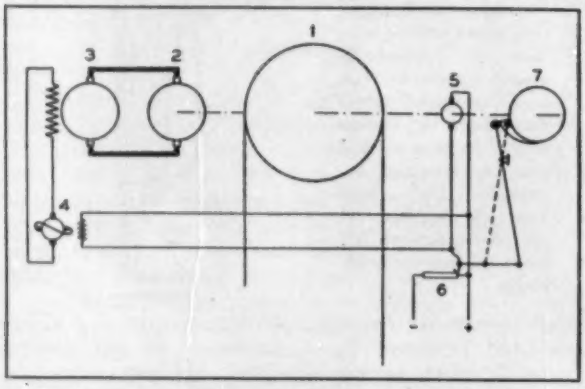
Section through Swedish installation at Grangesberg shows friction drive hoist in conventional ground installation. This is a conversion of a drum hoist to friction drive. Equipment and structure remained unchanged: Only hoist drum was modified. Inset photograph at left shows the concrete headframe.

Both Ward-Leonard driven and ac motor driven automatic hoists are provided with closed loop control, wherein the speed regulation impulse is obtained from the difference between a stabilized reference voltage and the voltage of a tachometer generator driven from the hoist. In the Ward-Leonard system the resulting differential current is fed into the main excitation winding of a metadyne generator, whose armature is connected to the field winding of the Ward-Leonard generator. By this means the hoist motor armature voltage is regulated until the tachometer generator voltage is practically equal to the imposed reference voltage.

With ac motor driven hoists of moderate outputs, the differential current is fed into the coil of a very sensitive and quick acting air or oil pressure regulator. This regulator actuates the service brake and corrects for possible deviations of the hoist speed from the predetermined speeds set for every point

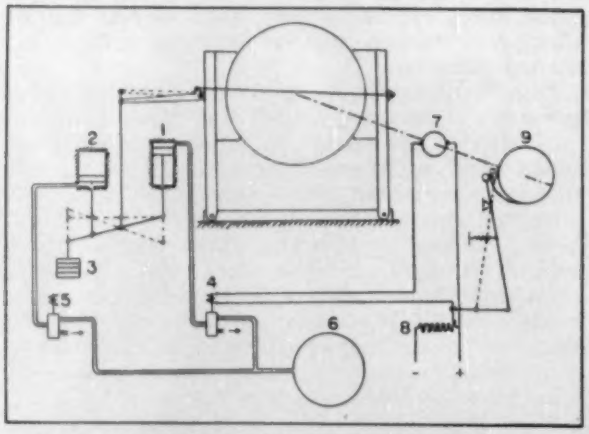
Electric depth indicators mounted in center of control desk are part of this push-button installation.

in the shaft. During the acceleration and full speed period no brake pressure is applied, but as soon as the retardation impulse is given a potentiometer rheostat driven from the hoist alters the reference voltage according to the desired retardation. At the same time secondary resistance is connected into the rotor circuit of the hoist motor, reducing its driving torque to an insignificant value. As soon as creeping speed is reached the motor torque is increased sufficiently to pull ascending load to the destination level. With ascending load most of the retardation torque is obtained from the unbalanced load so that the mechanical brakes have to contribute very little to the braking action. With descending load the brakes have to develop the necessary retardation torque plus the torque necessary for balancing the static load. The hoist motor speed is regulated in the same manner as is usual with manual operation. However, the introduction of automatic control clearly reduces the mechanical braking effort to a minimum, as the possibility of faulty operation by a hoist operator is eliminated.



Fundamental circuit diagram of a metadyne regulated hoist powered by a dc motor.

1. Driving pulley
2. Hoist motor
3. W.L. generator
4. Metadyne
5. Tachometer generator
6. Potentiometer rheostat
7. Cam gear



Air operated brake system for push button-operated, ac-motor driven hoist.

1. Service brake cylinder
2. Emergency brake cylinder
3. Brake weight
4. Service brake regulating valve
5. Emergency brake valve
6. Air receiver
7. Tachometer generator
8. Potentiometer rheostat
9. Cam gear

For ac motor driven hoists of larger outputs, which have to take care of a considerable amount of lowering duty, retardation down to creeping speed is obtained by dynamic braking whereby dc current is fed into the stator of the hoist motor by means of a metadyne generator. The main excitation winding of this metadyne is supplied by the differential current, giving the speed regulation impulse in the same manner as for Ward-Leonard control. At the same time the secondary resistance of the hoist motor is regulated automatically with reference to that speed which is necessary to obtain stable dynamic braking conditions. With ascending load the hoist motor is reconnected to the ac supply as soon as creeping speed is attained; speed regulation thereafter being transferred to mechanical braking action in the same manner as described above.

The simplicity and low cost of the ac motor system employing automatic speed regulation through braking is causing increased consideration of it.

Leveling Devices and Automatic Synchronizers: For accurate spotting of the skip or cage at various levels the following conditions must be fulfilled:

a) The hoist speed must be constant, independent of varying load. This is obtained by the very accurate metadyne control for the dc motor driven hoists. For ac motor driven hoists the full speed varies but little with the load.

b) Retardation impulse must be given with great accuracy at a constant distance from the spotting point. This is done by a high precision floor selector having magnet contacts that can be adjusted easily for operation at any desired point in the shaft. This floor selector is driven from the hoist and automatically synchronizes once in each complete hoisting cycle. The synchronizing device is described below.

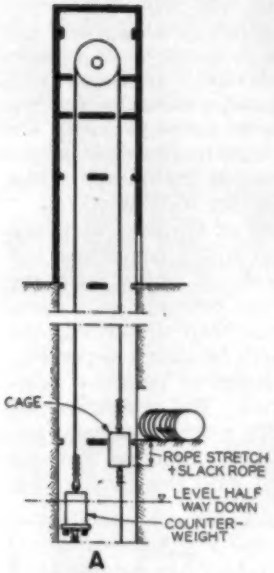
c) The retardation curve (speed vs retardation distance) must be followed with the highest possible accuracy in order to decrease the unavoidable creeping distance before the stopping point to a minimum. This is done by the closed loop control, discussed above, which affords the highest precision control available.

d) The actual stopping point must not vary to any marked degree. The stopping impulse is obtained from magnetic contacts installed in the shaft and actuated by permanent magnets on the conveyances. A low creeping speed is obtained by the closed loop control system which together with the quick service brake action results in high decking accuracy.

The photographs on page 39 show the floor selector driven from the hoist, with magnet contacts giving the retardation impulse at the different levels. Each

Changing Hoist and Tail Ropes

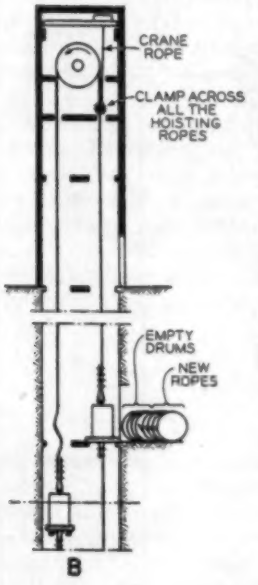
For a Friction Drive Installation



A

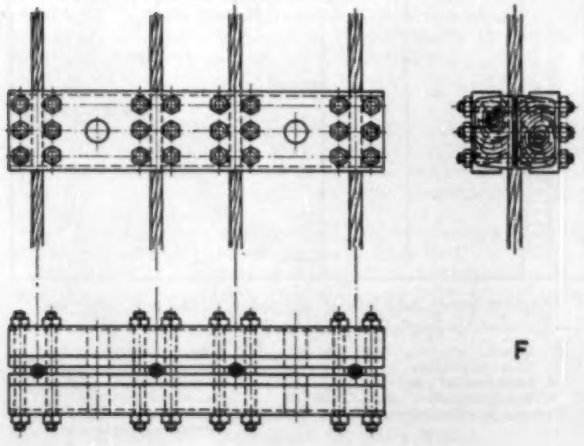
Replacing the hoisting ropes.

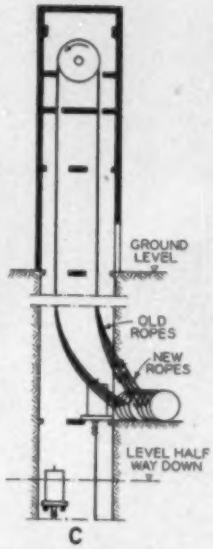
1. The drums with the new ropes and a corresponding number of empty drums for the old are taken to a level corresponding as nearly as possible to half the depth of the shaft.
The cage is driven to the same level as the drums and is lowered below that level by an amount which corresponds to the calculated rope stretch (about 3 in. per 100 ft of rope) and in addition by an amount corresponding to the length required in the form of slack rope so that the counterweight (or the other cage) can easily be fitted to the other end of the rope.
In this position the counterweight is supported.—**A**.



B

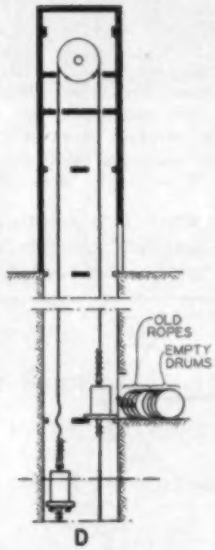
2. A clamp (**F**), powerful enough to carry the cage and half the weight of the ropes, is fitted across all of the ropes on the cage side close to the hoist but leaving sufficient space to raise the cage to the level chosen.
With the aid of this clamp and the crane in the hoist room, and while the hoist is driven in the corresponding direction, the cage is raised to the selected level, where it is supported on beams and the clamp removed.—**B**.


F



C

3. The old hoisting ropes are removed from the cage and the counterweight. They cannot slide as they hang across the driving pulley and are very nearly balanced.
The ends of the old ropes on one side are fixed in the empty cable drums and the ends on the other side to the new hoisting ropes.
The hoist is then driven slowly in such a direction that the new ropes will be wound off their drums, at the same time as the old ropes are wound up on the empty drums.—**C**.
The balance of the ropes will not be disturbed during this process.



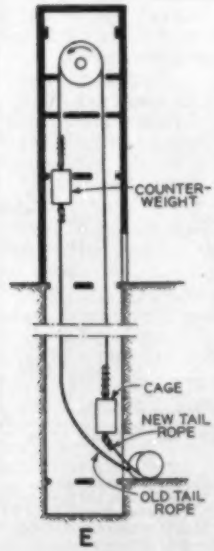
D

4. After the new ropes have been adjusted to the correct length and fitted with thimbles, they are fixed to the cage and the counterweight.—**D**.
After this the rope clamp and the crane are used again to raise the cage so that the supporting beams can be removed, after which the cage is lowered until the ropes are taut.
After the clamp has been removed, the counterweight is lifted by means of the hoist so that the supports can be removed.

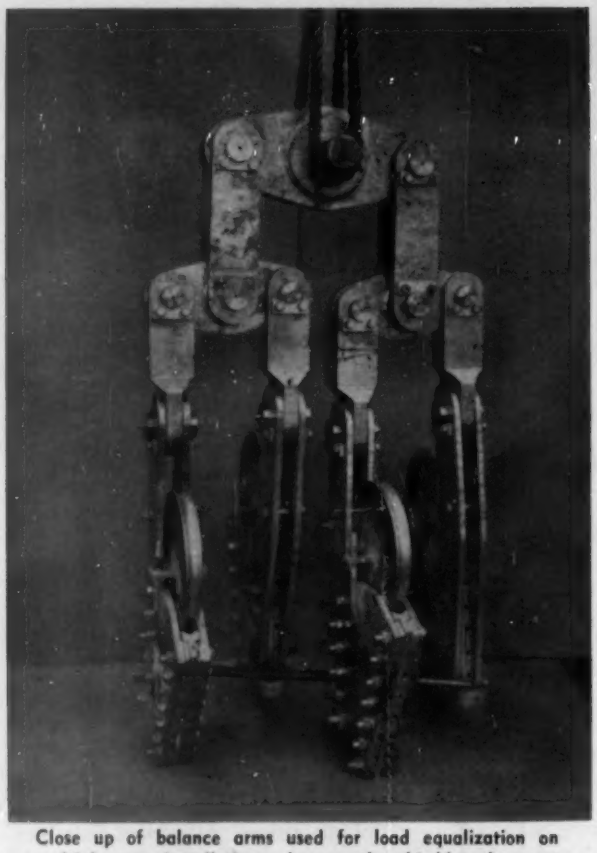
Replacing the tail rope.

1. The drum with the new tail rope together with an empty drum for the old rope are transported to the lowest level.
The old tail rope is freed from the cage and the thimble replaced on the new rope, which is afterwards fitted to the cage.
The free end of the old rope is fixed to the empty drum.—**E**.

2. While the cage is slowly raised, the new rope is unwound from its drum at the same time as the old rope is wound up on the empty drum.
When the counterweight has arrived at the lowest level, the old rope is removed, after which the new rope is adjusted for length and fitted in place.
(If the tail rope consists of several ropes, all of them are changed simultaneously.)

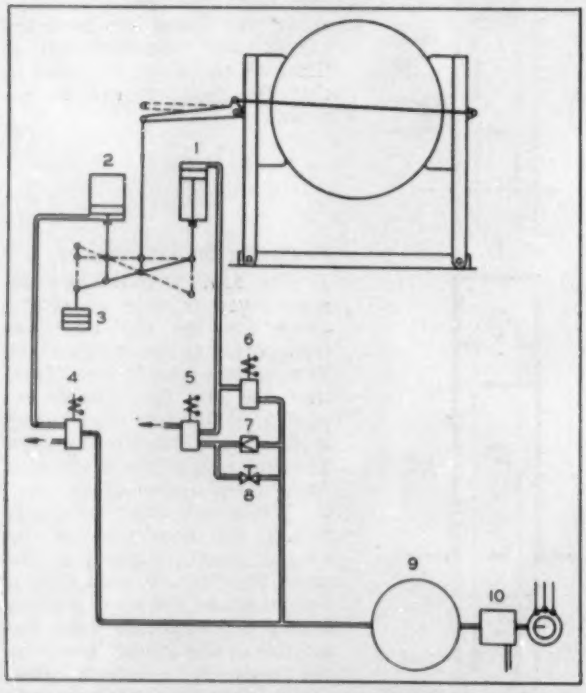


E



Close up of balance arms used for load equalization on multiple rope installations. In use, the thimbles shown at bottom in the photograph carry the four ropes and the skip is suspended by the pin at the top.

magnet contact is operated only when two rotating members carrying permanent magnets occupy a certain position when passing before the contact.



Pneumatically operated braking system for friction drive hoist having Ward-Leonard control.

1. Service brake cylinder
2. Emergency brake cylinder
3. Brake weight
4. Emergency brake valve
5. Service brake valve
6. Quick brake valve
7. Reducing valve
8. Needle valve
9. Air receiver
10. Compressor

With the two members rotating at slightly different speeds, there is only one point in the shaft where they coincide to actuate the contact. This design gives a very high degree of accuracy, negligible mechanical wear, and very simple adjustment of the different contacts.

Creep of the rope, as distinct from slip, takes place on the pulley, particularly when varying loads are hoisted in succession. Hence, it is necessary to provide a creep compensating device that periodically synchronizes the controlling and protective devices, driven from the hoist, with the conveyance in the shaft. This synchronization is generally done at the most frequently used level, i.e., at the dumping station for skips and at the collar for men hoisting.

If the conveyance is stopped at the level at which synchronizing is effected, and if the protective and controlling devices are exactly in phase with the conveyance position, a pair of contacts will open. If, however, synchronism has been disturbed, one or the other of the contacts will be closed depending on whether the hoist is advanced or retarded relative to the conveyance position. The synchronizing motor is then energized to drive the protective and controlling devices in the proper direction to bring them into correct relationship with the conveyance.

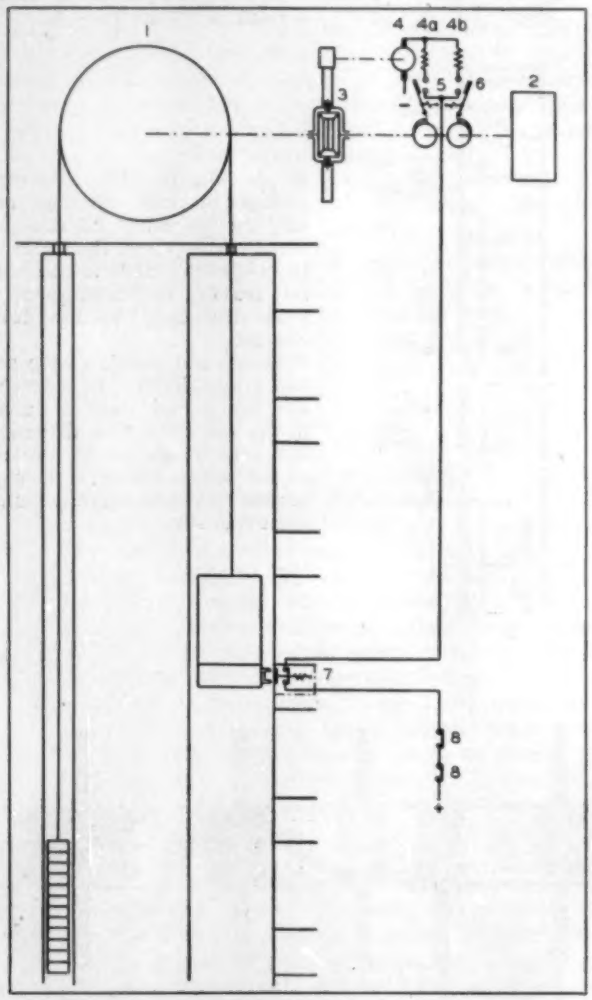
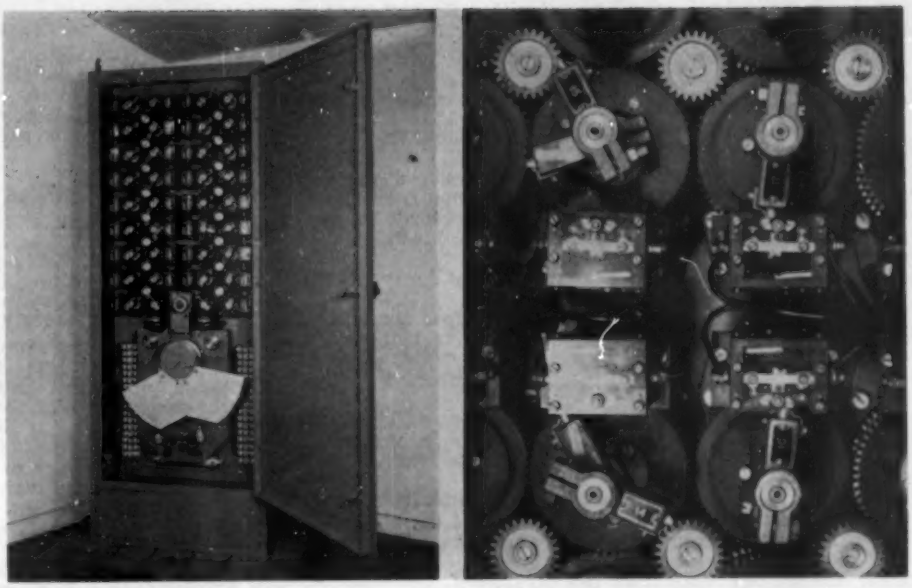


Diagram shows principle of operation of the automatic synchronizer for friction drive hoists.

1. Hoist
2. Hoist regulator
3. Differential gear
4. Synchronizing motor; a and b, directional fields
5. Synchronizing contact
6. Synchronizing contact
7. Cage position contact, magnet operated
8. Auxiliary contacts on reversing contactor



View of floor selector and leveling device for friction drive hoisting. Magnet contacts give the retardation impulse at the different levels. Each magnet contact is operated only when two rotating members carrying permanent magnets occupy a certain position when passing before the contact. With the two members rotating at slightly different speeds, there is only one point in the shaft where they coincide to actuate the contact.

Safety Devices: Besides the normal safety devices assuring protection against overspeed, overwind, overload, etc., a number of extra safety features have been introduced to check the correct operation of the different hoist details. They wholly eliminate the necessity of supervising the hoist in service. Among these features are protection against faulty brake operation during every start and stop, excessive wear of brake lining, and interruption in the drive of the protective and controlling devices. A detecting device for rope slip is provided that applies the emergency brake if the hoist continues to run after rope movement stops. This situation may occur if a descending conveyance becomes jammed in the guides, or arrested in the taper guides. In such a case the rope pressure may be relieved and the hoist would continue to rotate, with the ropes slipping on the drum and causing resulting wear on the friction grooves.

All these different devices have been developed as a result of years of experience with skip and cage hoisting in Sweden, where most of the hoists commissioned during the last ten years are operated automatically and completely unattended and where automatic hoisting has definitely proved itself more economical and safer than manual operation.

The writers wish to thank the officials and staff of The Cleveland-Cliffs Iron Co. and Freeport Sulphur Co., particularly James Westwater of CCI and Forbes Wilson of Freeport, for interest and assistance.

References

[1] E. S. Little and C. M. Barrett: Observations on Friction Hoists. *Canadian Mining Journal*. (Jan. 1954) No. 1, 75, p. 51, and (March 1954) No. 3, 75, p. 49.
[2] F. Landau: Design Principles for Friction Drive Hoists. *ASEA Journal*. (Nov.-Dec. 1953) 26, p. 155.
[3] U. S. Bureau of Mines Bulletin No. 75: Rules and Regulations for Metal Mines.

Tentative Model Code for Friction Drive Hoists

Prepared by E. S. Little and C. M. Barrett

Ed. Note: (This material is presented for information only, as representing one Canadian approach to the safety and regulation problem raised by the increasing number of friction drive hoisting installations on this continent. Reprinted from the March 1954 Canadian Mining Journal.)

As a result of observations and discussions with operators, manufacturers and government inspection bodies in Europe, the following Tentative Model Code has been devised as a guide to operators in Ontario contemplating the use of the friction hoist.

Ropes

Hoisting Ropes

(1) When a rope is installed, the factor of safety shall not be less than that as determined from the following formula: — F. of S. = 9.5 — .00075 × d, where d is the maximum length of rope suspended below the head sheave in feet.

(2) The factor of safety shall not be less than 5.5 for any depth of shaft when a rope is installed.

(3) When the breaking strength in any portion of a hoisting rope has fallen below 90 per cent of the original breaking strength, the rope shall be discarded.

(4) When the number of broken wires in a rope exceeds 6 in any section equal to the length of one lay, the rope shall be discarded.

(5) When the rate of stretch in a rope begins to show a rapid increase over the normal stretch noted during service, the rope shall be discarded.

(6) When marked corrosion occurs, the rope shall be discarded.

(7) Ropes shall be galvanized where conditions warrant.

(8) In the case of multiple-rope hoisting, the hoisting ropes shall be removed simultaneously.

(9) Measurements of rope diameters shall be recorded monthly.

(10) Location and number of broken wires shall be recorded monthly.

(11) Measurement of rope stretch shall be recorded during the life of the rope.

(12) Ropes shall be examined for visual defects daily.

(13) Rope dressing which would in any way enhance the danger of slippage on the drum shall not be used.

(14) The life of a hoisting rope shall not exceed two years except by permission from the Chief Inspector in writing after the rope and rope records have been examined by the operator and Mechanical Inspector.

(15) Hoisting ropes shall not be spliced.

(16) Hoisting ropes shall be tested by the Ontario Government Rope Testing Laboratory before being put into service. Where multiple ropes are used and in manufacture have been laid up continuously, a specimen shall be submitted for test cut from the portion between each pair of ropes. In the case of four ropes, two specimens shall therefore be required. In the case of three ropes, two test specimens shall be required.

(17) Test specimens shall be submitted for test and/or examination during the life of the rope if and when available, and as close to six monthly intervals as possible.

Tail Ropes

(1) When the tail rope is installed, the factor of safety shall not be less than 7.
(2) The life of a tail rope shall not exceed three years except by obtaining written permission from the Chief Inspector after the rope and rope records have been examined by the operator and Mechanical Inspector.
(3) Tail ropes shall be examined daily for visible defects.
(4) At least once in each month tail ropes shall be examined for broken wires and other defects and a record kept of same.
(5) Tail ropes shall be dressed when necessary to prevent corrosion.
(6) In the case of tail ropes, manufacturer's breaking strength, and other rope data shall be submitted to the Department of Mines before the rope is put into service.
(7) Test pieces of tail ropes shall be submitted for examination and/or test during the life of the rope if and when available, and as close to six monthly intervals as possible.
(8) Round tail ropes shall not be spliced.

Attachments

(1) Rope attachments to the conveyance shall have a factor of safety of not less than 10.
(2) All attachments shall be examined daily for visible defects.
(3) All attachments shall be thoroughly examined weekly.

Conveyances

(1) Where men are transported, the conveyance shall be fitted with approved safety dogs.
(2) The safety dogs on the conveyance shall be designed to perform satisfactorily under maximum hoisting speed and maximum man-load conditions including the weight of all rope. The weight of tail rope involved need not be used during the testing but calculations shall be made and included with the test reports to indicate probable results for the total weights involved.
(3) Present regulations applicable to conveyances shall be complied with in friction hoisting.
(4) A certificate of the load capacity of the conveyance shall be obtained from the manufacturer.

Hoists

(1) The drum diameter shall not be less than 80 times the diameter of the rope.
(2) The coefficient of friction between the rope treat and the rope shall be such that there is no possibility of slippage under normal operating conditions.
(3) The tread pressure of the rope on the tread shall be such that the wear on the tread is not excessive.
(4) A certificate stating the maximum suspended load rating shall be obtained from the manufacturer.
(5) When a friction hoist is used as a drum hoist for sinking purposes, the rules pertaining to drum hoists shall apply.
(6) The complete proposal for the installation of a friction hoist shall be submitted to the Chief Inspector of Mines for approval prior to its installation.

Loading

(1) The maximum material load allowed on the conveyance shall be determined from the lesser of the following calculations as outlined in (a) and (b).
(a) Maximum allowable suspended load on the hoist less weight of hoisting ropes less weight of tail ropes less weight of conveyances and attachments.
(b) Breaking strength of rope. Required factor of safety less weight of conveyance less the maximum weight of rope sheave to bottom landing. In multiple ropes, the lowest breaking strength of any rope shall be used in load calculations.
(c) The unbalanced load on the hoist as rated by the manufacturer shall not be exceeded.
(d) The maximum allowable load on the conveyance shall not be greater than that for which the conveyance was rated by the manufacturer.

(2) The maximum man-load shall be determined as follows:
(a) 85/100 (maximum material load + weight of conveyance) less weight of conveyance.
(b) The weight of the man-load shall, if necessary, be further reduced to provide adequate space for the transport of men without overcrowding the conveyance.

Rope Treads

(1) Rope treads shall be constructed of suitable, proven material.
(2) Treads shall be inspected regularly and maintained in good condition.

Safety Devices

(1) In general, the same safety devices shall be required for a friction hoist as for a drum hoist. Suitable overwind, underwind, and overspeed protection shall be provided and retardation devices shall be used where necessary.
(2) Where the contrivance affording such protection is driven from the drum shaft and where it is necessary to disconnect the contrivance for the purpose of adjustment, provision shall be made that the emergency brake is automatically applied when such disconnection is made.
(3) Tapered guides shall be installed above and below the limits of regular travel of the conveyance, arranged so as to brake and stop an overwound or underwound cage in the event of failure of the other devices.

Brakes

(1) The brakes for a friction hoist shall be designed to stop and hold the conveyance under maximum unbalanced loading conditions.
(2) Two separate brakes shall be provided, either of which will meet the requirement of item No. 1 and one of which will be automatically applied in case of emergency.
(3) The rate of emergency brake application shall be so regulated that slippage of the rope on the drum will not occur.

Depth Indicators

Depth indicators shall be driven from the drum shaft and where it is necessary to disconnect the indicators for the purpose of adjustment, provision shall be made that the hoist emergency brake is automatically applied when such disconnection is made.

Head Sheaves

(1) In the case of ground friction hoists, the head sheave diameter shall conform to the diameter of the hoist drum.
(2) Deflection sheaves shall be inspected and maintained as required by the present rules for head sheaves.

Chairs

The use of chairs, keps or other devices which would relieve the tension on the rope or ropes shall be prohibited.

Shaft

The water in the shaft sump shall be kept at such a level that the tail ropes will at no time be passing through sump water.

Inspection and Test

Daily, weekly, and monthly tests and inspections of mechanical and electrical equipment shall be made and recorded as required under the present rules for drum hoists.

DIAGRAMS FOR SLUDGE-CORE COMBINING METHOD ARE AVAILABLE

Full size prints of the figures in the article by G. C. Waterman, *Chuquicamata Develops Better Method for Evaluating Core Drill Sludge Samples*, page 54, are available by writing to: Editor, MINING ENGINEERING, 29 West 39th Street, New York 18, N.Y. These include the complete table of combining factors, a portion of which is shown on page 58.

Hydrothermal Alteration

at the

Climax Molybdenite Deposit

by John W Vanderwilt and Robert U. King

THE Climax molybdenite deposit in Lake County 100 miles southwest of Denver is located in the central part of the mineral belt extending northeasterly across the state. Principal geographic features and geology are shown on Fig. 1. The first period of molybdenite mining, which began in 1918, ended in April 1919 because of limited demand and a price drop to about 72¢ per lb. During this time the ore came from the Leal level and surface outcrops at a higher elevation. Rate of mining was 250 tpd and several million tons of ore averaging 0.7 pct molybdenite were developed.

Since April 1924, when the second period* began, Climax Molybdenum Co. has been the only operating company. Production in 1924 was 400 tpd and finding ore was a continual problem. When the White tunnel was extended, however, further ore was encountered. The orebody was thought to be tabular until 1926, when B. S. Butler recognized the relation of the developed ore on the Leal and White levels to a central area of fine-grained hydrothermal quartz, and by 1929 diamond drilling had blocked out indicated ore reserves in excess of 100 million tons.

* Refs. 1-4 describe the early mining activity; Refs. 5-9 cover the early part of the second period of mine operation.

In 1946, on the basis of information obtained from 25 miles of mine workings and a completed exploratory program involving over 200,000 ft of diamond drilling, the present authors reviewed and brought up to date the geology of the orebody. More recently Sears,[9] employing microscopic techniques, made a study of hydrothermal alteration and mineralization, and Howell and Schassberger[10] restudied available geologic data.

Production (1953) of molybdenite ore has been expanded to over 25,000 tpd and total production from 1918 through 1953 has been:

Molybdenum (Mo)		453,451,153 lb
Tungsten (WO_3)	(1949 to 1953 inclusive)	1,973,086 lb
Tin	(1949 to 1953 inclusive)	121,420 lb
Pyrite	(1949 to 1953 inclusive)	65,000 tons

J. W VANDERWILT, Member AIME, is a Mining Geologist and President of the Colorado School of Mines, Golden, Colo. R. U. KING, Member AIME, is a Geologist, U. S. Geological Survey, Golden, Colo.

Discussion on this paper, TP 3909I, may be sent (2 copies) to AIME before March 31, 1955. Manuscript, June 18, 1954. New York Meeting, February 1954.

Tungsten, tin, and pyrite are byproducts and monazite also was produced from 1949 through 1951, after which it was not saved. A maximum of 15 to 20 tons of monazite was produced.

Geology of the Area

Pre-Cambrian crystalline rocks constitute most of the Mosquito Range for several miles to the north, east, and south of the Climax molybdenite deposit, see Fig. 1. To the west the crystalline rocks are in fault contact with shales and sandstones of Pennsylvanian age. Both crystalline rocks and sediments are intruded by dikes and sills of Tertiary age. Numerous faults with small displacements are to be found in the crystalline rocks east of the Mosquito fault and in the sedimentary beds to the west.

Pre-Cambrian Rocks: The pre-Cambrian rocks consist of schist and gneiss, identified with the Idaho Springs formation, and granite with minor pegmatite correlated with the Silver Plume granite of the Silver Plume area.

The Idaho Springs formation is a general term applied to pre-Cambrian schist and gneiss found over a large part of the Colorado Front Range. At Climax this formation consists largely of biotite-schist and quartz-biotite gneiss with minor quantities of plagioclase and orthoclase, although in places appreciable quantities of feldspar and quartz are present in the more gneissic varieties. Locally, especially along the contact with granite, recrystallization of the schist has produced coarser texture and a more pronounced than average gneissic appearance. The gneiss and schist have been mapped as a single unit by Butler and Vanderwilt (1933)[11] and by Singewald (1951).[12] Schist predominates at the higher elevations of the Mosquito Range and in the area to the north and east of Climax. The regional trend of schistosity is northeast with varying dips to the east.

Silver Plume granite and associated pegmatite intrudes the Idaho Springs formation. Silver Plume granite in many places and in the Climax district in particular has an irregular form, and many large and small inclusions of schist and gneiss occur within the granite. Granite predominates at the surface in the immediate vicinity of the area of hydrothermal alteration and extends for several miles to the northeast and southeast. As more schist is present at lower levels of the mine than in the upper levels, the suggestion is that the granite is sill-like in form,

The Transactions papers appearing in Mining Engineering during 1955 will subsequently appear in AIME Transactions Vol. 202 and may be permanently referenced to that volume.

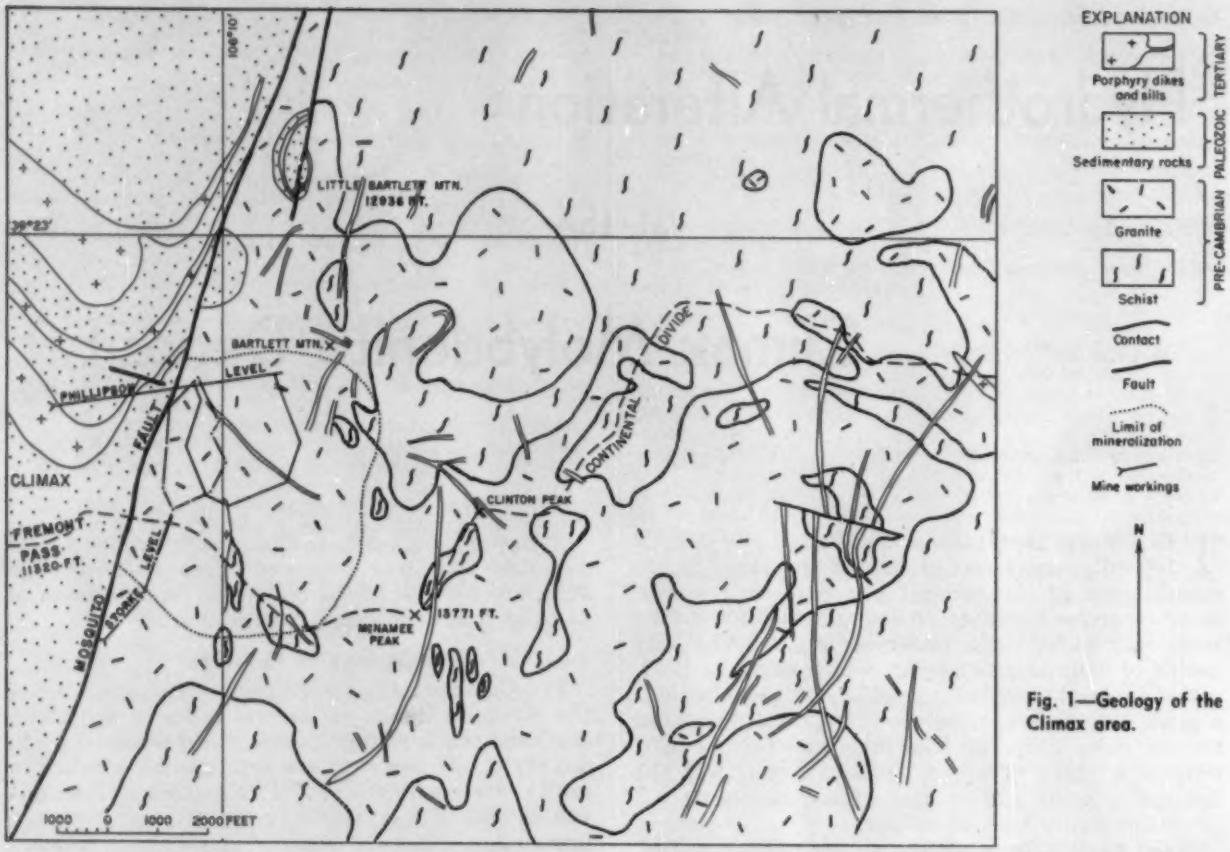


Fig. 1—Geology of the Climax area.

dipping easterly with the regional structure of the Idaho Springs formation.

The granite is a gray to pink medium-grained rock. A characteristic feature of weathered surfaces of the granite is its trachytoid texture, due to a rough alignment of tabular feldspar. Predominating minerals are microcline, orthoclase, quartz, biotite, and muscovite.

Paleozoic Sedimentary Rocks: The Paleozoic sedimentary formations consist of gray sandstone with gray to black shale and a few thin beds of limestone of Pennsylvanian age. In the vicinity of Little Bartlett Mountain, a mile north of Climax, there are two small areas of Sawatch quartzite of Cambrian age; they are the only sedimentary rocks east of the Mosquito fault in the vicinity of Climax.

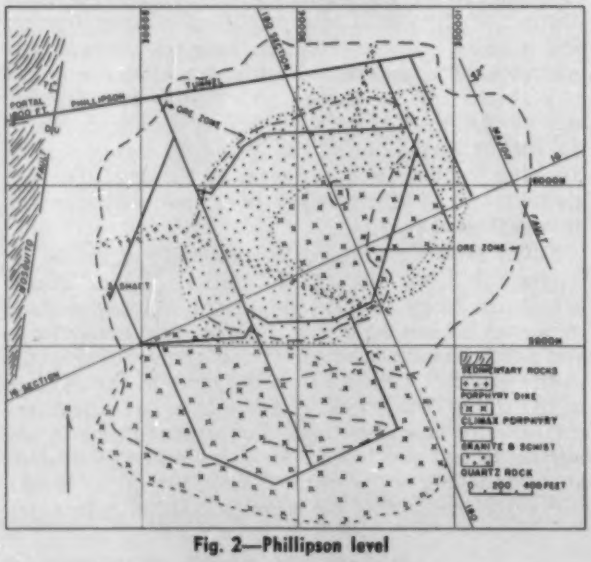


Fig. 2—Phillipson level

Tertiary Igneous Rocks: Igneous rock presumably of early Tertiary age forms dikes and stocks in the pre-Cambrian crystalline rocks and sills and dikes in the Pennsylvanian shales and sandstones. These intrusive bodies are generally similar in composition and range from a quartz monzonite to diorite, quartz monzonite being the predominant type.

Porphyry dikes are a common feature in the crystalline rocks throughout the extent of the Mosquito Range from Leadville northward. These dikes intersect all other formations and therefore represent the last recognized igneous intrusive rocks. They are characterized by conspicuous quartz and large orthoclase phenocrysts in a fine-grained to aphanitic groundmass. Small plagioclase phenocrysts and biotite are common. The margins of the dikes commonly are felsitic.

In the vicinity of the Climax molybdenite deposit, as in adjoining areas, the more basic dikes are the older and quartz monzonite the younger; detailed correlation is difficult. Quartz monzonite porphyry dikes with large orthoclase phenocrysts are called Lincoln porphyry because of similarity with sills found on Lincoln Mountain several miles to the east. The terms *porphyry* or *quartz porphyry dike* find common usage for those light-colored dikes in which quartz or feldspar predominate.

Within the area of hydrothermal alteration all dikes are altered. In some there is sufficient molybdenite to make good ore and in others, including dikes within the main ore zone, molybdenite is rare. Relatively little plagioclase escaped alteration, and the resulting rock is mineralogically granite.

Dikes are 10 to 50 ft wide and vary in length; some are traceable for a mile or more. North-northwesterly and north-northeasterly trends and steep dips predominate.

Plans and Sections Show Porphyry Stock with Domal Top at Climax

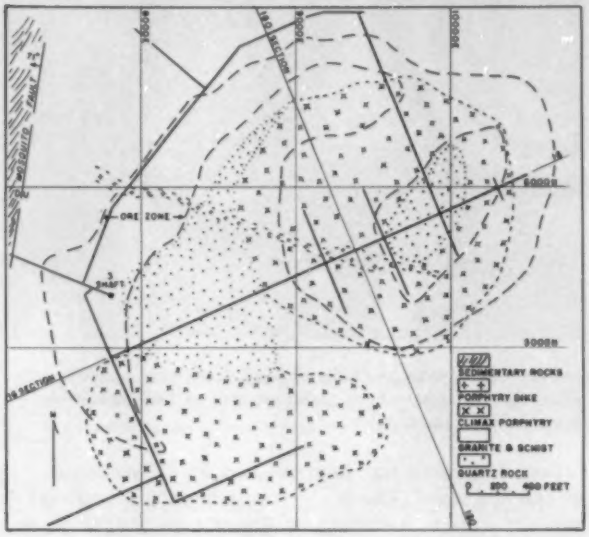


Fig. 3—500 level

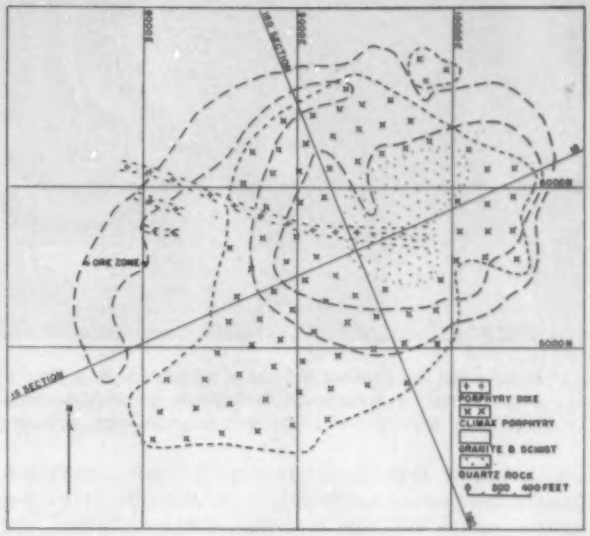


Fig. 4—750 level

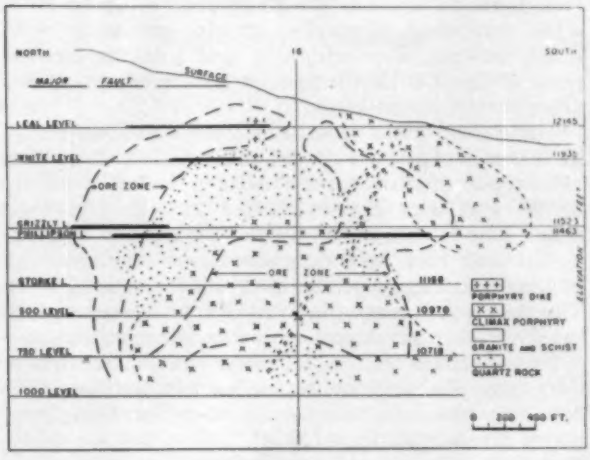


Fig. 5—180 Section

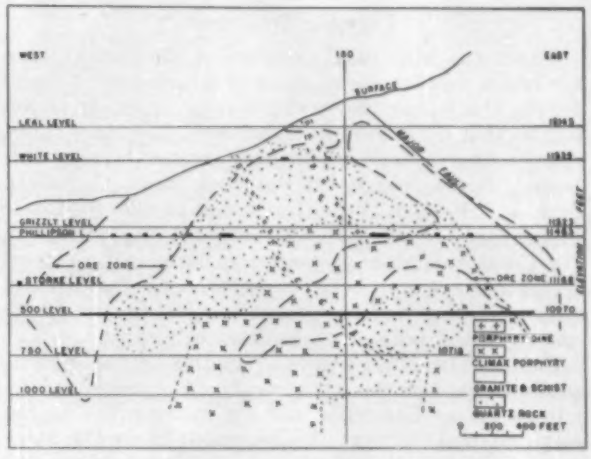


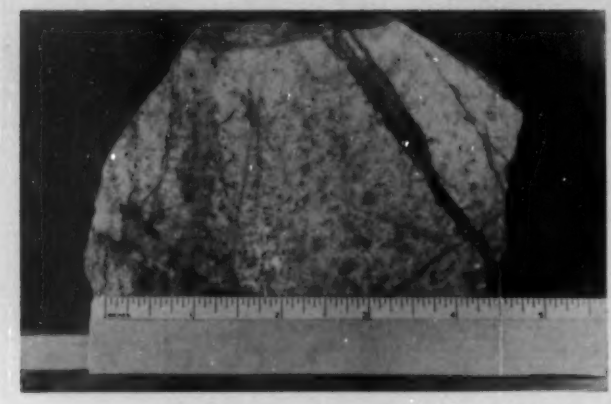
Fig. 6—16 Section

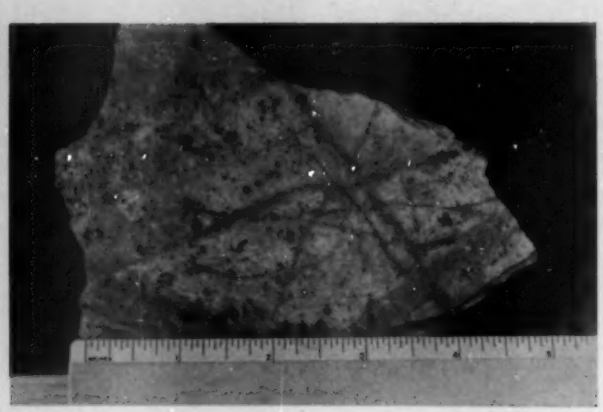
Climax Porphyry Stock: Several quartz monzonite stocks of Tertiary age occur in the mineral belt in central Colorado and two in the Mosquito Range near Climax. One such stock is located a little northeast of Kokomo about 5 miles from Climax, and another crops out to the southeast near the head of Buckskin Gulch. More distant are the Montezuma stock, at Montezuma 30 miles to the northeast, and the Princeton batholith northeast of Salida 55 miles to the south. In reality these rocks range in composition from monzonite to granite and the average seems to be intermediate between quartz monzonite and granodiorite. The authors follow Ransom in using quartz monzonite for the group. Crawford (1924),[18] who studied these stocks, interpreted them as evidence of the presence of a large batholith underlying the area of Mt. Princeton on the southwest to Montezuma on the northeast, a distance of about 85 miles.

Within the area of hydrothermal alteration at Climax a porphyry stock, see Figs. 2-6, with a domal top has been identified and mapped in many of the mine workings and diamond drillholes. This stock is tentatively correlated with the group referred to above. It is circular in plan and the most pronounced hydrothermal alteration has occurred above and around the upper part. The stock extends from 100 ft above the Phillipson level, see Figs. 5 and 6, to below the limit of diamond drilling 700 to 1000 ft below the Phillipson level. To the southwest of the main stock a branch or arm of the porphyry extending upward was mapped at surface in a small area stripped of its soil cover in preparation for mining. The porphyry is light gray to pink and is medium-grained and massive, with characteristic quartz and orthoclase phenocrysts in a fine-grained quartz orthoclase groundmass, see Fig. 7.

When first encountered the porphyry stock was called *early porphyry* because it contained greater concentrations of molybdenite than had been found in porphyry dikes; this was considered suggestive of relative age. Somewhat later, dikes with an abundance of molybdenite were found intersecting the porphyry stock. To avoid the general confusion arising from use of an age designation the term *Climax porphyry* was introduced by Howell and Schassberger (1953).[30]

The Climax porphyry, like the dikes, has undergone hydrothermal alteration which eliminated plagioclase and left a rock which mineralogically is granite. Plagioclase is rare above the 500 level but albite-oligoclase occurs in increasing amounts with





Figs. 7a and 7b—Polished surfaces of Climax porphyry. Fig. 7a (left)—From central area on Phillipson level. Note large proportion of phenocrysts to groundmass. Dark bands are molybdenite-quartz veins. Fig. 7b (right)—From southwest area on Phillipson level. Note small proportion of phenocrysts to groundmass. Gray bands are molybdenite-quartz veins.

depth below this level. This relationship and the quartz monzonite composition of the stocks in the nearby areas are the basis for the belief that the original composition of the Climax porphyry was quartz monzonite.

Tectonic Structure

The major structural features of the Climax area are faults and fractures, most of which were formed during the Laramide revolution or later. It is assumed that earlier jointing occurred. Tertiary igneous activity is believed to have existed during this period. Some folding of the rock since Cambrian time is indicated by the attitudes of the Paleozoic sedimentary formation. Structures originating in pre-Cambrian time, other than intersecting joint systems, have not been recognized in the Climax area as having had important bearing on the localization of the area of hydrothermal alteration.

Faults: The Mosquito fault bounding the molybdenite deposit on the west, see Fig. 1, extends southerly as far as Leadville and for many miles to the north beyond Climax. Displacement along the Mosquito fault has placed the pre-Cambrian rocks opposite Paleozoic formations. East of Climax the fault strikes N 10° E and dips 72° W. It is normal, with displacement estimated between 2000 and 7000 ft. Pennsylvanian sedimentary rocks with included porphyry sills are dragged up sharply against the fault on the west or hanging wall. Cambrian quartzite that caps some of the higher peaks of the Tenmile Range dips 20° to 25° E on the Continental Divide, a few miles east of Climax, but it dips westerly east of the Mosquito fault in the vicinity of Little Bartlett Mountain and also 10 miles to the south in the northern part of the Leadville district.[14] This structure in the quartzite suggests that a broad monoclinal fold existed in the sedimentary rocks before movement on the Mosquito fault originated.

Faults with small displacements that offset Tertiary porphyry dikes are common everywhere in the Mosquito Range.

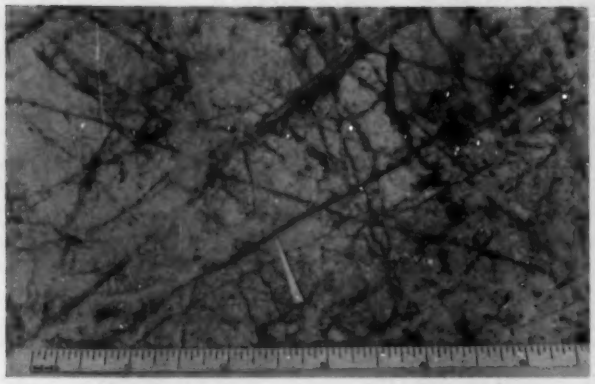
In the upper levels of the Climax mine a strong fractured zone known as the Major fault, also called East fault, flanks the molybdenite orebody on the northeast. The fault strikes N 23° W and dips 42° easterly. Recognized early during the mining operations, this zone was originally thought to have offset the orebody. Subsequent exploration of the orebody by drifting and diamond drilling has not provided conclusive evidence to show whether the orebody or Tertiary dikes that cross the zone are offset. The zone has been traced in drillholes as far as the 500 level. The Major fault is poorly exposed at surface and is believed to die out to the southeast because it could not be identified in good rock outcrops flanking Tenmile Creek. In the mine workings and diamond drilling the fault zone is 10 to 50 ft wide, consisting of crushed granite and schist with much sericite, clay minerals, and local concentrations of fluorite. Discontinuous slickensided surfaces are common in the zone.

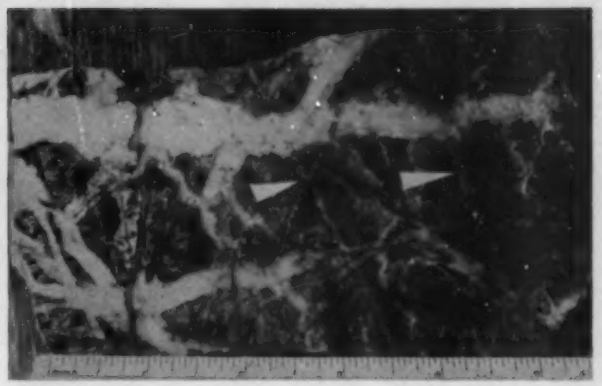
The second most prominent fractured zone occurs in the westerly part of the mineralized area. This west shear zone is curved, with a strike N 50° to 80°W, and dips approximately 25°NE. The west shear zone is recognized by the occurrence of brecciated wall rock and molybdenite ore cemented by banded and vuggy quartz over widths of 2 to 50 ft. The zone cuts across the orebody and is exposed on the Phillipson level and on lower mine workings.

Irregularities in the ore-zone boundaries where they cross the west shear zone have at various times been regarded as evidence of post-mineral displacement. Evans and King (1939)[15] calculated a possible direction of movement on the west shear zone by projecting irregularities in ore zone limits and porphyry dikes from the nearest drift or drillhole intersections. However, such irregularities are no greater adjacent to the west shear zone than where faults are not present.

Pattern of Fracturing: Closely spaced fractures, some of which exhibit typical joint patterns, are found throughout the mineralized area at Climax and surrounding area. The number of fractures increases gradually from about one per foot, typical of the unaltered pre-Cambrian country rock, toward the zone of greatest molybdenite concentration where the fractures are spaced as close as one per inch. Late dike rocks that have cross-cutting relationships with the pre-Cambrian rocks, ore zones, and quartz rock also are highly fractured but to a lesser degree than the pre-Cambrian rocks. The intricate pattern of fracturing at Climax was noted early. Billingsley and Lyon (1918)[16] in their mapping of the Leal level believed that many of the fractures were faults with small displacement.

In the Phillipson tunnel northwesterly alignment of fracturing is evident. Early attempts were made to map and plot all joints, fractures, and veins in an unsuccessful effort to discover a possible structural control of the orebody. A plot of the strike of several hundred fractures of all sizes produced two maxima: N 10° to 15°W and N 15° to 20°E, the greater





Figs. 8a and 8b— Molybdenite-quartz veins. Fig. 8a (left)—Typical ore. Silver Plume granite with molydbenite-quartz veins. White marker points to a pyrite-quartz-topaz vein. Uniform texture is typical of granite. Fig. 8b (right)—Typical ore. Schist of the Idaho Springs formation with molybdenite-quartz veins. White markers point to pyrite-quartz-topaz veins.

number in the group having the northeast strike. These two maxima may represent a conjugate system of fractures related to early movement on the Mosquito fault. Many Tertiary porphyry dikes, Fig. 1, have northeast strikes in the Climax vicinity.

Hydrothermal Alteration

The most valuable guides for directing exploratory diamond drilling to extend the ore zone was its relation to the quartz rock and the relation of the quartz rock to the Climax porphyry. A proper understanding of these relationships is considered essential for an understanding of hydrothermal alteration and its origin at Climax.

Relationships are too complex for clear description and therefore frequent reference is recommended to the mine plans and sections shown in Figs. 2-6.

Molybdenite, found throughout the altered area, is regarded as an integral part of the problem of hydrothermal alteration. Mine workings and diamond drill core were sampled at 10-ft intervals for determination of molybdenite content. As a result more is known about concentration and distribution of the molybdenite than any other feature related to the alteration. The ore zone, see Figs. 2-6, which includes 0.4 pct molybdenite and higher, being well established quantitatively, becomes a useful reference zone for comparing rock alteration and other hydrothermal changes that have occurred. However, it should be kept in mind that the ore zone is bounded by assays representing an economic limit; like other features of hydrothermal alteration, the changes in the molybdenite content are gradational.

Deposition of molybdenite and related hydrothermal alteration extends over an area about a mile in diameter in Tenmile Amphitheatre immediately east of the Mosquito fault, see Fig. 1. At surface the area is marked by limonite-stained granite and schist.

Mine workings and related diamond drilling concentrated in the central part of the area limit observation on the Leal level to an area 1400 by 1600 ft and on the 500 level to an area 3200 by 4000 ft. Observations in marginal areas are confined to scattered weathered outcrops and one diamond drillhole to the north, one to the east, and one to the south of the mine workings.

Changes produced by hydrothermal alteration are least in the marginal area and greatest in the central area, from the surface to the greatest depths reached by exploratory work. Changes in rock alteration are gradational throughout the area.

The area of hydrothermal alteration is characterized by 1—numerous closely spaced and intersecting small veins and 2—pronounced alteration of rock between the veinlets. These features are to be found in each rock type.

Small Veins: On the basis of the relative age relationships and mineral content, three types of veinlets occur, 1—molybdenite-quartz, 2—pyrite-topaz-quartz, and sericite and topaz.

Molybdenite-Quartz Veins: The majority of the quartz-molybdenite veins, see Fig. 8, are less than ¼ in. wide; a few veins are ½ in. wide. The molybdenite in small well-formed crystals is concentrated along the walls of the veins and commonly quartz is the only gangue mineral. Varying amounts of orthoclase, sericite, pyrite, and fluorite usually are present in scattered grains in the central parts of the veins. Orthoclase also occurs along the walls of the veins and in places sericite encases the molybdenite or is otherwise closely associated with it. The grain size of the minerals contained in the veins is a millimeter or less.

It would be appropriate to refer to this group of veins merely as quartz veinlets containing varying amounts of molybdenite, orthoclase, fluorite, pyrite, and sericite. The molybdenite content is not the same in all the veins and its distribution along the strike of a given vein is not uniform. The extremes in mineral composition are milky quartz with no molybdenite to molybdenite veinlets with negligible amounts of quartz. However, the term *molybdenite-quartz* is used because molybdenite is present in the majority of the veins and is characteristic of the group as distinguished from the other groups which do not contain molybdenite.

In the outer part of the area of hydrothermal alteration, the number of quartz veinlets is small and the number increases gradually towards the central area. In the ore zone, see Figs. 8a and 8b, over widths of 300 to 500 ft, see Figs. 2-6, the number of molybdenite-quartz veinlets averages 10 to 12 or more per ft and it is not possible to find a piece of rock of average hand-specimen size that does not contain several molybdenite-quartz veinlets. Above the Phillipson level, the ore zone is continuous around an elliptical area of fine-grained quartz. Passing from the ore zone to the fine-grained quartz, over a distance of 10 to 50 ft, the veins increase in number and width toward the central area until they merge to form continuous fine-grained quartz. The molybdenite content gradually decreases to less than 0.2 pct in the quartz rock.

The molybdenite-quartz veinlets stand out conspicuously in hand specimens because of the concentrations of molybdenite. However, the walls are not always well defined. Under a hand lens, the boundaries of the veinlets are indistinct, and under a microscope, see Fig. 9, the minerals in the veins show an irregular and gradational relationship with the quartz and orthoclase of the wall rock, suggesting a replacement origin of the veins.

The molybdenite-quartz veinlets are well developed in each rock type in the ore zone. Veinlets with molybdenite and a minimum of quartz are characteristic in areas of schist, and such veinlets present surfaces of weakness which tend to break open, exposing fracture surfaces coated with molybdenite. Some of the porphyry dikes do not show an appreciable amount of molybdenite, whereas others contain as many veinlets as other rock types. The differences noted in schist and porphyry dikes are attributed to differences in the amount of fracturing.

Pyrite-Quartz-Topaz Veins: The pyrite-quartz-topaz veinlets, see Fig. 8, are less numerous than the molybdenite-quartz veinlets, across which they cut. They range from ⅛ to ¼ in. wide. The quartz occurs along the walls and the pyrite with topaz usually along the central part, although it is common for the pyrite and topaz, occurring together or separately, to occupy the full width of parts of the veins. These veins are surfaces of weakness, and when they are broken open fracture surfaces spotted or coated with pyrite are common.

The minerals characteristic of the pyrite-quartz-topaz veins are hubnerite** and small quantities of chalcopyrite, galena, sphalerite, rhodochrosite, sericite, and fluorite. Molybdenite is not present and only occasional grains of orthoclase were observed. Topaz is characteristically associated with the pyrite. The hubnerite occurs in laths or diamond-shaped crystals frozen to the walls of the veins. Small cavities lined with quartz, topaz, sericite, and locally cassiterite and sulphides are common features of these veins. The sharp walls and the cavities occurring along the center suggest that these veinlets are filled fractures.

** Hubnerite was first described by Butler and Vanderwilt (1931) on the basis of microscopic observations on color, cleavage, and streak. Somewhat later large hand-picked crystals from a quartz vein were identified as wolframite on the basis of chemical analyses made by chemists of the Climax Molybdenum Co. and it was assumed that the fine-grained variety also had the same iron content. Recently Haines[18] identified the fine-grained tungsten mineral as hubnerite on the basis of X-ray diffraction studies.

The average grain size of the silicate minerals and fluorite is about 1 mm and that of the sulphides 2 to 3 mm. The topaz grains are anhedral except for some grains that have orthorhombic elongations and show basal cleavage. With a few exceptions topaz can be recognized only microscopically.

The cross-cutting relationship of this group of veins with the molybdenite-quartz veins, the relative abundance of pyrite, and the absence of molybdenite serve to identify them as a group. They occur with general uniformity throughout the area explored by mine workings and related diamond drilling, but whether they extend as far as molybdenite-quartz veinlets is not known. In the porphyry dikes and in the large area of fine-grained replacement quartz, the pyrite-quartz veinlets, which probably average 1 to 2 per ft over large areas, also show general uniformity.

Sericite and Topaz Veins: Topaz veins, see Fig. 10, many of which are only a few millimeters wide, and small sericite veins are common; they cut across pyrite-quartz veinlets. Topaz and sericite occur together in the same vein or separately in different veins. Scattered grains of pyrite are common. Sericite frequently occurs along joints, particularly in the area of fine-grained quartz.

Kaolinite and montmorillonite occur in the sericite and topaz veinlets. These clay minerals have been identified by X-ray diffraction patterns. Microscopic identification has not been satisfactory and detailed relationships are not fully known.

Rock Alteration Between Veins: Alteration between the veinlets includes development and/or introduction of the same minerals that make up the three groups of veins described above. For convenience of discussion the area of alteration has been subdivided into three parts, each grading into the adjoining one: 1—the marginal area outside the ore zone, 2—the ore zone, and 3—the quartz rock.

Marginal Area Outside the Ore Zone: For reasons stated earlier it has not been possible to study in detail the extreme outer part of the area of alteration. At distances of 500 to 1000 ft from the outer limit of the ore zone the rock shows sufficient impregnation of pyrite to produce, upon weathering, limonite-stained outcrops. The biotite shows bleaching and replacement by muscovite. Clay and sericite alteration occurs in the plagioclase, leaving orthoclase less altered. Throughout the area outside the ore zone identification of the granite, schist, and porphyry in thin sections or in hand specimens is relatively easy.

Within 100 to 200 ft of the ore zone considerable secondary orthoclase and quartz have developed, replacing plagioclase, orthoclase, and muscovite in the granite and Tertiary porphyry rocks. Replacement of schist by quartz and orthoclase often is preceded by conversion of the biotite to fine-grained muscovite. Quartz-orthoclase replacement is usually proportional to the number of molybdenite-quartz veinlets present. As a rule rock identification in the marginal area outside the ore zone is not difficult, especially in thin section, because of original minerals which can be recognized.

Rock Types in the Ore Zone

Identification of rock types in the ore zone is difficult, especially in the area close to the quartz rock. Individual hand specimens or thin sections are insufficient to distinguish one rock type from another; dependable identification can be made only by observation of gradual changes from the outer areas where positive identification is possible. Transition between the fine-grained quartz rock and the ore zone, in which identification of rock types is difficult, varies in width as follows: fine-grained quartz area and other rocks, 10 to 50 ft; Silver Plume granite and schist, 0 to 25 ft; porphyry dikes and other rocks, 0 to 5 ft; and porphyry stock and Silver Plume granite, 50 to 100 ft.

Schist tends to resist alteration more than either granite or porphyry; however, within the ore zone the concentration of molybdenite is as great and the orthoclase replacement as pronounced in schist as in granite or porphyry. Even in highly altered areas schist is relatively easy to identify in places because of the remnants of biotite or the presence of fine-grained muscovite and sericite oriented parallel to the original foliation of the schist.

Silver Plume granite in the ore zone is a fine-grained mixture, see Fig. 11, of water-clear secondary orthoclase and quartz with varying amounts of sericite, fluorite, and other minerals. Remnants

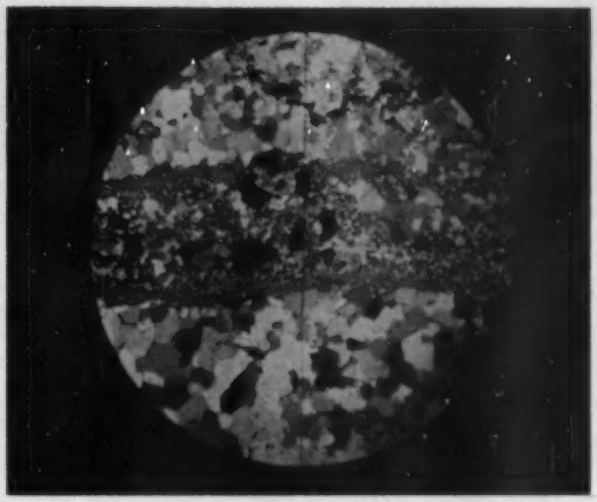
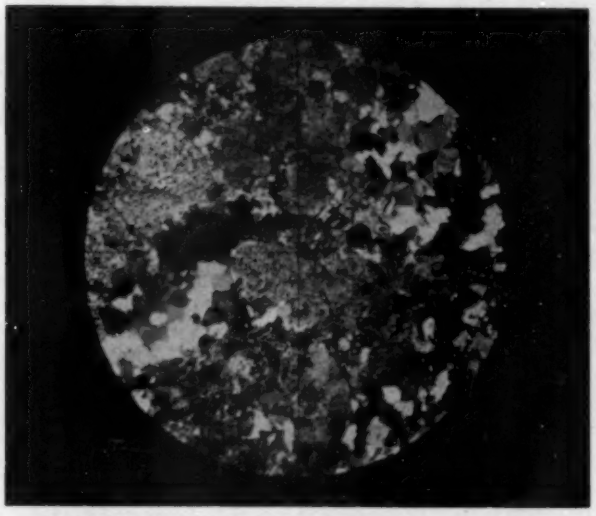


Fig. 9 (left)—Photomicrograph of molybdenite-quartz veins. Molybdenite (black) along one wall of a molybdenite-quartz vein (below) in gradational contact with granite (above). X24. Fig. 10 (right)—Topaz vein, with quartz and pyrite along central part, in ore zone in granite. X24. Crossed nicols.



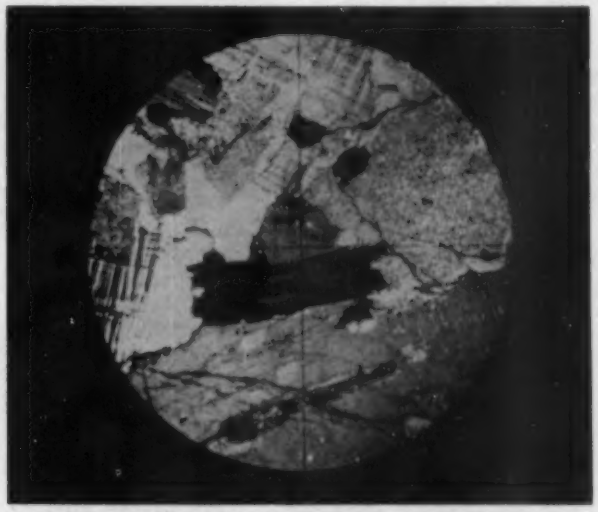
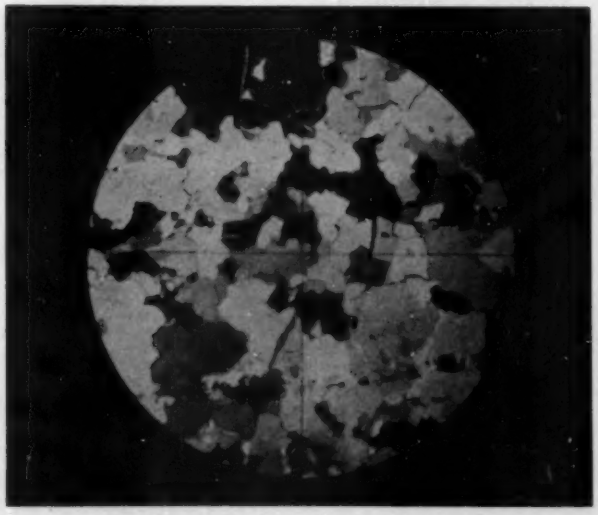


Fig. 11 (left)—Typical granite alteration between veins in ore zone. Large speckled gray areas are primary orthoclase. Clear gray and white areas are secondary orthoclase and quartz. Black hexagonal plates and laths are molybdenite. Light areas partly surrounding molybdenite are sericite. Small grains of high relief in primary orthoclase are fluorite. X24. Fig. 12 (right)—Silver Plume granite from the west slope of Bartlett Mountain north of the caved area. Orthoclase, gray; microcline, cross-lattice structure; quartz, white; and biotite, dark gray to black in center and upper left. X24.



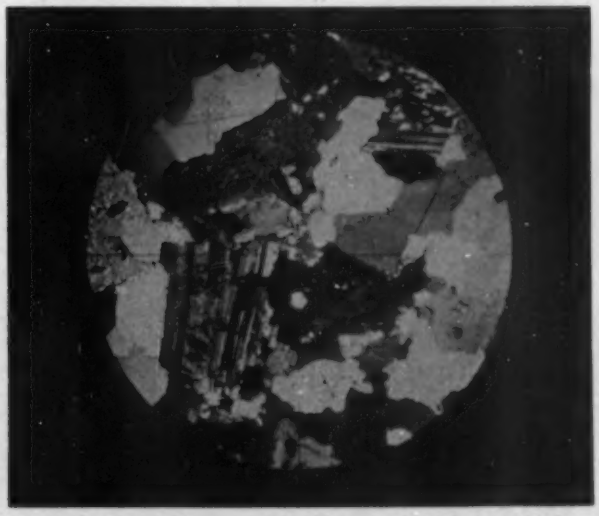


Fig. 13 (left)—Quartz rock. X24. Crossed nicols. Fig. 14 (right)—Albite-oligoclase in Climax porphyry from 700 ft below the 500 level. X24. Crossed nicols.

of altered and partly replaced cloudy primary orthoclase are common. The cross-lattice structure of the microcline, plagioclase, biotite, muscovite, and magnetite characteristic of the Silver Plume granite, see Fig. 12, are not found in the granite in the ore zone.

The Silver Plume granite and Climax porphyry are particularly difficult to tell apart in the ore zone except in areas where quartz phenocrysts are present. Porphyry dikes usually retain a pronounced porphyritic texture and thus are easy to identify.

In the ore zone hydrothermal or secondary orthoclase replacement predominates over quartz replacement. The orthoclase and quartz, as seen under the microscope, replace the primary minerals along crystal boundaries and to some extent along cleavage planes. Cross-cutting veinlets also occur. Sericite occurs in the primary orthoclase and interstitial to the other minerals. Quartz replacement predominates over orthoclase in the transition between the ore zone and fine-grained quartz.

Quartz Rock: A large mass of fine-grained quartz somewhat like quartzite is exposed at the surface in the central part of the area of hydrothermal alteration. In reports prior to 1924 the quartz rock has been referred to as *quartzite, alaskite, aplite,* and *pegmatite*. Butler and Vanderwilt (1933)[11] described it as highly silicified rock. The quartz rock forms a massive cap 600 ft thick over the domal top of a porphyry stock, see Figs. 5 and 6, the top of which is several hundred feet below the surface and about 100 ft below the Phillipson level. On the Phillipson level, see Fig. 2, the quartz rock covers an elliptical area measuring 1400 by 1900 ft. On this level the porphyry stock occupies a circular area 800 ft across, completely surrounded by the fine-grained quartz. The fine-grained quartz blankets the north and west flanks of the porphyry stock to depths ranging 500 to 700 ft below the Phillipson level, but it extends only a short distance below this level on the south and east side of the stock, compare Figs. 3 and 4. Although contacts with other rock units are gradational, as stated earlier, the quartz rock is an easy unit to map; its texture and light-gray to white color set it apart from other rocks in the area of hydrothermal alteration.

The texture of the quartz rock is uniform, consisting of equidimensional grains averaging 1 mm or slightly less in diameter, see Fig. 13. On the basis of one chemical analysis (Butler and Vanderwilt 1933),[11] thin-section studies, and examination of diamond drill core, it can be stated with confidence that a quartz content of 98 pct prevails over large areas. Minor quantities of orthoclase, scattered grains of molybdenite, hubnerite, fluorite, sericite, and topaz are common. Molybdenite content ranges from 0.01 to 0.3 pct. Locally pyrite-quartz veinlets and sericite and topaz veinlets are present, usually with clay minerals.

The ore zone is adjacent and outside the quartz rock, but typical molybdenite-quartz veinlets, characteristic of the ore zone, are not present in the area of fine-grained quartz. In places close to the ore zone indistinct bands and parallel streaks of molybdenite occur which suggest replacement remnants of earlier molybdenite-quartz veins.

A second area of quartz rock, see Figs. 3 and 4, geologically and mineralogically like the first, occurs several hundred feet below the domal top of the porphyry stock. On the 500 level this second area of quartz rock has a horizontal extent of 400 by 800 ft. Diamond drilling has not fully outlined the extent of this second quartz area, but to the depth reached the size is relatively small compared with the first and larger area described.

The quartz rock is regarded as a replacement largely of Silver Plume granite and Idaho Springs formation and, to some extent, the Climax porphyry. The fine-grained quartz grades into the ore zone, and in the interval of transition remnants of the rock found in the adjoining ore zone are present. Megascopically and microscopically the fine-grained quartz in the molybdenite-quartz veins is like the quartz in the large area of quartz rock. This invariable gradational change from quartz rock to granite, schist, and porphyry is the basis for the belief that the fine-grained quartz area is a hydrothermal replacement of these rocks.

Hypogene Minerals

With reference to **adularia,** see the paragraph under **orthoclase,** p. 49.

Albite is lacking or occurs only in minor amounts above the 500 level and for some distance below in the Climax porphyry. Below the 500 level Howell and Schassberger (1953)[20] report secondary albite. The authors, who have observed albite-oligoclase only at depths greater than 300 to 600 ft below the 500 level, see Fig. 14, regard these as original constituents of the Climax porphyry.

Allophane is listed in the paragraphs under **clay minerals** and **sericite,** p. 50.

Brannerite is present in minor quantities as small rectangular elongated euhedral crystals associated with quartz and hubnerite.

Chalcopyrite is present in small quantities in pyrite-topaz-quartz veins and commonly is associated with fluorite in the larger fractures. Galena and sphalerite are associated minerals.

Cassiterite was identified in the course of metallurgical research by the research staff of Climax Molybdenum Co. Sears (1952)[9] describes cassiterite as occurring 1—with molybdenite as the older of the two; 2—in sericitized areas; 3—in relatively large and angular grains related to quartz-topaz, which carries hubnerite and cuts across the earlier quartz-molybdenite veins; and 4—between biotite plates in unaltered schist cut by quartz veinlets. Cassiterite seems to have been deposited before molybdenite and also definitely later. In schist it occurs in dark straw-yellow rounded grains of less than 0.02 mm diam and in granite in dark reddish angular grains. Sears believes the cassiterite may be a reconcentration of an earlier deposited mineral by Tertiary hydrothermal solutions.

Dickite is mentioned under **clay minerals,** p. 50.

Fluorite is widespread in its occurrence. It may be red, purple, green or colorless. Scattered anhedral microscopic grains are common in the groundmass of the rock throughout the area of hydrothermal alteration including the quartz rock. Fluorite is characteristic in small amounts in the molybdenite-quartz, pyrite-topaz-quartz, and topaz-sericite veinlets. It occurs as lenses 6 to 12 in. thick in larger fractures like the Major or East fault and west shear zone. On the north slope of Ceresco Ridge well outside the ore zone a 14-in. vein of white fluorite has been noted. In the larger fissures fluorite occurs alone or with minor amounts of chalcopyrite, galena, and sphalerite.

Galena, present as occasional grains in pyrite-topaz-quartz veinlets, is commonly associated with sphalerite and chalcopyrite and with fluorite in larger fractures.

Halloysite is referred to under **clay minerals,** p. 50.

Hubnerite was first identified by Butler and Vanderwilt (1933)[11] on the basis of its optical properties. Later analyses of hand-picked crystals from a quartz vein indicated an iron content of wolframite, and this term was used for several years. More recently Haines (1953)[17] reported that an X-ray diffraction pattern for hubnerite had been obtained from a large crystal and from carefully cleaned grade *A* wolframite concentrate

containing 1.94 pct iron. Accordingly the mineral should be classed hubnerite.

The hubnerite at Climax is reddish to reddish brown in small grains and dark brown to black in larger grains. In thin section it is deep red. Crystal grains are irregular to lath and diamond-shaped forms.

The most common occurrence of hubnerite is in pyrite-topaz-quartz veins described earlier. It is present in scattered grains throughout the area of hydrothermal alteration and as finely disseminated grains along cleavage planes of fresh biotite in schist.[9] Hubnerite crystals up to 1 in. across and 1 to 2 in. long in quartz veins several inches wide have been noted in two places. These quartz veins show cavities lined with quartz crystals. Hubnerite in the form of such large crystals has no commercial significance; the fine-grained hubnerite has provided nearly 2 million pounds of tungsten (WO_3) since 1949. The tungsten (WO_3) content in the ore zone ranges from 0.02 to 0.04 pct over large areas, but concentrations of 0.1 pct WO_3 are common in 10 to 50-ft samples of diamond drill core and mine workings.

Ilmenorutile, identified in tungsten concentrate, has not been observed in thin sections or hand specimens. The grains are subhedral, suggesting tetragonal forms. Analyses by Ronzio (1951)[18] of carefully purified material showed 5.2 pct columbium and 6 pct iron. Spectrographic analyses show no tantalum present. The mineral is almost opaque; thin edges show brown color in strong transmitted light under the microscope.

Kaolinite is discussed under **clay minerals** and under **sericite,** p. 50.

On the basis of X-ray diffraction pattern **lepidolite** has been reported by Mielenz et al. (1952),[19] who described it "as reddish brown micaceous deposits associated with pyrite." Lithium has been reported as a trace element in spectrographic analyses, but this is to be expected in any micaceous rock. A chemical analysis of material selected for possible lepidolite failed to show more than a trace of lithium, and the presence of lepidolite must be considered questionable.

Mielenz et al.[19] report that **magnesite** and/or **bruennerite** occur as small anhedral to euhedral crystals and fine-grained masses in 6 of 23 samples across the ore zone on the Storke level. In a sample from the Major or East fault large rhombohedral crystals of magnesite were noted "in association with muscovite, quartz, fluorite, and small amounts of sphalerite, galena, and molybdenite." Both the index of refraction and X-ray diffraction pattern suggest the presence of the iron carbonate ($FeCO_3$) molecule.

Molybdenite, the important ore mineral, is found throughout the area of hydrothermal alteration. The crystals are tabular and six-sided, usually too small to be seen in the crystal form with a hand lens. Under a microscope hexagonal forms are common, but much of the molybdenite appears as black specks under ordinary magnifications. Haines (1953)[17] states that his X-ray studies show all minerals examined to be crystalline. The mineral is easy to recognize because of its metallic-gray to black color and its greasy softness like that of graphite. It is present as scattered flakes through the rock, usually associated with hydrothermal orthoclase and quartz. The most characteristic occurrence is in the quartz-molybdenite veinlets.

Montmorillonite is discussed under **clay minerals** and **sericite,** p. 50.

Monazite is a by-product in the recovery of hubnerite and in concentrated form shows a light golden brown color. In thin section the grains are nearly opaque and the grain size is but a fraction of a millimeter. The occurrence of monazite is similar to that of cassiterite. It has not been an important byproduct.

Muscovite is referred to under **sericite,** p. 50.

Orthoclase is exceeded in quantity only by quartz and in the ore zone predominates over quartz. It is the common product of hydrothermal alteration in areas between veins, it is common in molybdenite quartz veins, and it occurs sparingly in pyrite-topaz-quartz veinlets. Like quartz it replaces each rock type and is associated throughout the area with the other mineral products of hydrothermal alteration.

The fine-grained secondary quartz and orthoclase assemblage is the predominating groundmass throughout the ore zone, irrespective of rock type, granite, schist, porphyry dike, or Climax porphyry.

Pink feldspar in veins and in rock groundmass has been called **adularia** by Mielenz et al.[20] on the basis of its X-ray diffraction pattern that "differs slightly from that of typical orthoclase." Pinkish orthoclase, noted in each rock type, seems to be more common in the Climax porphyry and Silver Plume granite. Orthoclase as used in this report includes the pink feldspar.

With minor exceptions orthoclase is fine-grained and can be identified only under the microscope. In thin section it is characterized by water-clear anhedral grains measuring 1 mm or less. The usual feldspar twinning is uncommon. In contrast, original orthoclase is cloudy, with dusty inclusions tentatively identified by Mielenz[19] and by Sears[9] as allophane. The grain size of original orthoclase ranges from small grains to crystals 15 to 20 mm across, some of which show carlsbad twinning.

Fine-grained orthoclase predominates over quartz as a product of hydrothermal alteration of granite, schist, and porphyry in the ore zone and in the marginal area outside the ore zone.

Pyrite is widespread in its occurrence, probably even more so than molybdenite. In the ore zone the pyrite content is estimated to average 2 pct over large areas. The common crystal form is the cube. Poorly developed pyritohedrons also are present. Some pyrite is present in each type of veinlet, but it is particularly characteristic in the pyrite-topaz-quartz veins which intersect veins in the quartz-molybdenite group. Grain size usually is 1 mm or less; exceptions are pyrite cube faces 1 in. or more found locally in open parts of quartz veins.

Quartz, one of the most abundant minerals, constitutes 90 to 98 pct of the large area of quartz, 10 to 20 pct of the ore zone, and progressively lesser amounts in the marginal area of alteration outside the ore zone. Grain size of the quartz is uniform, and equidimensional grains are usually less than 1 mm. Numerous quartz crystals 1 by 3 mm to 2 by 5 mm occur in late sericite veins. Small quartz crystals commonly line small cavities found in pyrite-topaz-quartz veinlets.

Quartz replaces each of the rock minerals and is associated throughout the area of alteration with each other mineral product of hydrothermal alteration.

Rhodochrosite occurs sparingly in pyrite-topaz-quartz veins and frequently is associated with small amounts of sulphides of copper, lead, or zinc. It is easily recognized because of the characteristic pink color and rhombohedral cleavage.

Sphalerite occurs as dark brown to resinous brown crystals and grains in the group pyrite-topaz-quartz veins and commonly is associated with fluorite in the larger fractures. Galena and chalcopyrite are associating minerals.

Topaz occurs in each rock type. It is characteristic of veinlets which intersect molybdenite-quartz veinlets and it is common in the groundmass of the rock. Topaz is closely associated with pyrite in the pyrite-topaz-quartz veins, with sericite in late veins, occasionally with molybdenite and fluorite, and also alone in thin seams that cut across quartz veinlets. With rare exceptions it occurs in equidimensional microscopic grains and to a small extent elongated grains with cleavage normal to the long dimension.

In only two places have topaz crystals been found that were identifiable megascopically and one of these occurred in a sericite vein in the quartz rock. The topaz was in the form of a tabular aggregate of crystals with good crystal termination projecting in all directions, suggesting a crystal growth in a cavity. Perched on the topaz were quartz prisms coated by a few crystals of hubnerite and sericite.

It is estimated that the topaz content of the ore averages around 2 pct over large areas and analyses show a relatively high fluorine content.

Supergene Minerals

Molybdite, which also may be called ferromolybdite or molybdic ocher, is a fine-grained yellow earthy to fibrous mineral. It occurs characteristically at surface and within 100 ft of the surface. Along some fractures it is present to depths of several hundred feet. The recent development of molybdite was noted along the walls of the old Denver tunnel. Molybdite has not been a source of molybdenum production.

Limonite is widespread at the surface and gives to the area of alteration the typical yellow coloration of this mineral; reddish colors occur in places. Limonite is an alteration product of pyrite.

Jarosite is common as ocher-yellow incrustations along fractures near the surface.

Small coatings of **gypsum** noted on oxidized pyrite veinlets at surface have been regarded as a secondary mineral. More recently Mielenz et al. (1952)[19] noted minute anhedral crystals of gypsum along fractures of a few samples from the Storke level. A similar occurrence was noted on the Phillipson level. In ore samples the gypsum occurs as subradiate clusters and euhedral forms within crystals of orthoclase. These clusters are present only in the immediate vicinity of fractures. The Phillipson and Storke levels are several hundred feet below the surface and the gypsum noted is believed to have formed from mine waters.

The green coatings characteristic of **chalcanthite** is common locally on walls of mine workings.

Torbernite (Metatorbernite?) has been observed as pale green tabular tetragonal crystals with pyrite in late veins and as sparse disseminations in fresh appearing highly silicified rock.

Clay Minerals

Studies made by several geologists on argillation, in particular the work of Sales and Meyer (1948),[20] and Lovering (1950)[21] served to direct attention to the possible importance of clay minerals in the Climax molybdenite deposit. Two suites of samples selected at 100-ft intervals to represent two parallel sections across the ore zone were submitted to Mielenz, Schieltz, and King[19] for study. One suite of 10 samples came from 311 drift and one suite with 11 samples came from 317 drift, both on the Storke level 600 ft apart. The rock in this part of the ore zone is Silver Plume granite with some schist. Dickite was noted in only one sample where it occurred as euhedral (pseudohexagonal) crystals in seams cutting intermixed prismatic quartz and micro-crystalline kaolinite. Kaolinite was reported in each of the samples and montmorillonite intermixed with sericite and kaolinite in one sample from the outer part of the ore zone. Halloysite was reported in one sample and its presence was suspected in several others, but positive identification was not possible. The kaolinite occurs in fractures and in the rock in amounts termed abundant to rare, but a quantitative amount was not established.

Montmorillonite with intermixed sericite and kaolinite also was reported in samples from the Climax porphyry in the outer part of the ore zone on the Phillipson level. In a sample of Silver Plume granite from the Storke level adit, at a point outside the limit of recognized molybdenite deposition, montmorillonite with sericite, fine-grained muscovite, and kaolinite were found in small, soft, pink to white pockets as alteration products of original albite-oligoclase. Crystals of potash feldspar in the granite were comparatively fresh.

It was suggested by Mielenz et al. that there were two and possibly three generations of kaolinite in the samples taken from across the ore zone: 1—The earliest occur in veinlets and as patches within crystals of orthoclase and without other associating minerals and 2—as veinlets and coatings on fracture surfaces in association with large amounts of sericite and as fracture coatings intermixed with small prismatic crystals of quartz. 3—The last generation of kaolinite occurs sparsely in veinlets with large amounts of anhedral quartz and small amounts of sericite. The second and third generations of kaolinite are later than the quartz-molybdenite veinlets.

Sears[9] also reports the presence of kaolinite as relatively plentiful in the zone which includes the greatest concentrations of molybdenite, and outward in the less moderately altered rock. He points out that kaolinite occurs mainly in the granitic rock and recognizes two phases of argillation: "1—an early pre-molybdenite phase, which is confined to the alteration of the feldspars, resulted in the formation of allophane, kaolinite, and montmorillonite; 2—the post-molybdenite, or late phase, occurs mainly as fillings in late fractures. This late phase, which is restricted mainly to kaolinite, cuts early mineralized veinlets."

Sericite

Sericite occurs throughout the area of hydrothermal alteration. Its principal occurrences in general order of age of formation are: 1—in replacement of plagioclase, orthoclase, and muscovite; 2—in molybdenite-quartz veinlets; 3—in pyrite-quartz-topaz veinlets with topaz or fluorite; 4—in thin white veinlets with or without topaz; and 5—in the coating of joint surfaces.

Small amounts of sericite in orthoclase remnants and between quartz grains occur in the quartz rock.

In items 1, 4, and 5 above kaolinite is a common associating mineral with sericite. Sericite is not always present in molybdenite-quartz veinlets and when present occurs as small shreds between crystal boundaries or concentrated with molybdenite at the outer part of the veins. Occurrence of sericite in pyrite-quartz-topaz veinlets is somewhat analogous to that in the molybdenite-quartz veinlets; it may occur interstitial to quartz grains or in association with the topaz and quartz.

Sericite is a common alteration product of feldspar, but much of the original and secondary orthoclase in the Silver Plume granite is not associated with sericite. The same can be said for porphyry occurring in the stock. Direct invasion and replacement of biotite schist by quartz and orthoclase has been described; however, development of sericite in biotite schist also is common. First the biotite shows a bleaching to a muscovite, which in turn is replaced by a fine-grained mucovite or sericite. Remnants of biotite with sericite and continuous fine-grained muscovite or sericite with scattered remnants of biotite are characteristic features in thin sections of biotite schist from the ore zone. In the final stage of hydrothermal alteration, orthoclase and quartz replace sericitized schist. Gradational relationships and, by inference, an abundance of sericite (10 to 15 pct or more in areas of secondary quartz and orthoclase) suggest the original rock was biotite schist.

The work by Mielenz et al. had two objectives, to obtain direct information and to discover, if possible,

criteria other than direct identification to assist in mapping clay alteration in mine workings. Clay minerals are now recognized as an important product of hydrothermal alteration, but discovery of reliable criteria for rapid mapping remains unrealized.

Studies thus far have shown that sericite and clay minerals commonly occur together at Climax, suggesting a genetic relationship. They also occur separately. Sericite seems to have a wider distribution, particularly in the groundmass between veinlets. Some feel that clay minerals, allophane, montmorillonite, and kaolinite were formed first; however, Wagner (1953)[28] "definitely identified very finely divided grains of sericite associated with the kaolinite. The sericite grains are small, poorly formed and ragged. They range in size from 5-12 microns. The sericite is often missing in the thin sections as it apparently pulled out in preparation of the section. In sections that were specially prepared, the fine, ragged sericite is nearly always present and material washed from hand-specimens contained it."

Wagner also writes that in a later stage sericite is "much coarser than that in the earlier stage. The grains range from 100 to 500 microns in length. The mineral is much better formed than the earlier finely divided sericite and usually occurs as elongated individuals with ragged ends. The coarse sericite is chiefly confined to fractures and along grain boundaries. Molybdenite, zircon, cassiterite, wolframite, monazite, ilmenorutile, fluorite, topaz and pyrite occur along with the coarse sericite as fracture fillings."

Final conclusions as to the genesis of clay minerals and sericite must be deferred until more information is available.

The general effect on the original rock of hydrothermal alteration from the outer to the central area according to Butler and Vanderwilt[11] has been a progressive increase of silica and a decrease in all other oxides. Original rock minerals ultimately were replaced by fine-grained quartz rock.

In the ore zone the alumina content has been decreased as compared to unaltered granite, but the total orthoclase content has been increased because of the development of secondary orthoclase. The development of orthoclase may in large part represent recrystallization, since the indicated loss of alumina (Al_2O_3) and potash (K_2O) can be accounted for by destruction of mica. As compared with unaltered granite quartz increases by an amount that can be accounted for in large part by the quartz contained in the several kinds of veinlets. It is estimated that the various quartz veinlets make up 8 to 12 pct of the volume of the rock in the ore zone.

In the ore zone and adjoining areas muscovite, magnetite, and plagioclase are virtually absent and only small amounts of biotite remain locally in the schist. In the course of hydrothermal alteration sodium and calcium were among the first to be removed. The small amounts of calcium shown by analyses can be accounted for by the fluorite present.

Elements present in substantial quantities for which the hydrothermal origin is clear include molybdenum, sulphur, and fluorine. It is believed that tungsten, tin, copper, lead, zinc, and iron also were introduced by the same hydrothermal solutions carrying molybdenum, sulphur, and fluorine.

The writers believe that to understand hydrothermal alteration at Climax it is necessary to take into account the broad geologic relationships, see Figs. 2-6. Observation of the overall area of alteration is limited to vertical depth of only 2300 ft and this is confined to a horizontal area at all levels that is less than half the total area of hydrothermal alteration. In addition, erosion has removed an unknown height of the upper part of the alteration. Since it has been possible to observe in detail only a relatively small part of the total area of alteration, only tentative interpretations should be advanced.

Significant Geologic Relationships

Broad relationships considered well established include:

1—Lack of any definite pre-Cambrian structural control. The Silver Plume granite and regional schistose structure of the Idaho Springs formation extend for several miles beyond the area of hydrothermal alteration.

2—In composition, size, and number porphyry dikes in the vicinity of the Climax molybdenite deposit are the same as elsewhere in the Mosquito Range.

3—The Mosquito fault shows no material change in strike, dip, or other structure near Climax.

4—As measured by replacement of quartz and orthoclase, development of clay minerals and sericite, and deposition of molybdenite, hydrothermal alteration is greatest in a central area and decreases gradually outward.

5—In position and form the several characteristic features of alteration of the Climax molybdenite deposit show a number of striking relationships to the Climax porphyry stock.

Origin of the Climax Porphyry Stock: The southwesterly area of the Climax porphyry on the Phillipson level was encountered first around 1934 in the southerly extension of 300 drift and in exploratory diamond drillholes directed horizontal to the southwest from this drift. The rock is characterized by quartz phenocrysts in a quartz-orthoclase groundmass. Except for the quartz phenocrysts the rock resembles the altered Silver Plume granite. The quartz phenocrysts and especially the larger ones are aggregates of quartz grains, with random orientation suggestive of crushing and/or recrystallization. Similar features have been noted in thin sections from diamond drill core from the quartz monzonite porphyry stock a few miles northeast of Kokomo.

Hydrothermal alteration has affected the Climax porphyry in the same manner as the granite and schist. Original mica and plagioclase are difficult to find except below the 500 level in the southerly part of the stock. The porphyritic texture is the conspicuous feature which serves to make the Climax porphyry a mappable unit easy to recognize, although in places the contact is difficult to establish. In mapping the greatest difficulty occurs in places where hydrothermal alteration is strong and where the porphyry is in contact with the quartz rock and pre-Cambrian granite. The boundary between Climax porphyry and schist is relatively sharp and is not difficult to establish.

Vanderwilt at first favored hydrothermal origin, but the form of the Climax porphyry as established by mine development and diamond drilling led the authors, by 1939, to the conclusion that the porphyry originated as an igneous intrusion. Recently Sears[9] and Howell and Schassberger[10] have favored the replacement origin.

In addition to the form of the Climax porphyry there are other features indicative of an igneous

origin: 1—A fine-grained transition or chill phase, in which phenocrysts are absent or inconspicuous, is found along the margins of the porphyry. 2—The contact with surrounding schist and granite is relatively sharp in areas of lesser hydrothermal alteration. 3—Granite and schist inclusions are absent in the porphyry. 4—There is a gradational change in depth to quartz-monzonite with remnants of albite-oligoclase and fresh biotite. 5—The rock is porphyrytic.

Lack of Uniform Alteration in Porphyry Dikes: Certain porphyry dikes are altered as strongly as are the granite, schist, and Climax porphyry. Others contain little or no molybdenite or quartz-molybdenite veinlets. Pyrite-topaz-quartz, topaz-sericite, and sericite veinlets are present in all porphyry dikes. These differences were recognized during the early development of the mine, and as mine workings advanced much time was spent in studying dike contacts. These studies were handicapped by the common occurrence of late fractures with sericite along or near the contact which obscured detailed relationships. Frozen contacts, suggestive of a post-mineral intrusive relationship, were noted; however, a small penetration of molybdenite either in small veins or as scattered crystals invariably was found in even the freshest-looking dike. Two explanations are offered: 1—The less altered porphyry dikes were intruded after the molybdenite deposition was virtually completed but early enough to permit crystallization and fracturing before the pyrite-quartz and topaz-sericite veins formed. 2—Intrusion of the dikes just before hydrothermal alteration began and residual high temperatures and lack of jointing prevented access of the mineralizing solutions during early phases of hydrothermal activity. The writers accept the second explanation as the more plausible one.

Origin of the Deposit

The molybdenite deposit and associated hydrothermal alteration were regarded by Butler and Vanderwilt (1933)[11] as strong evidence of an underlying stock. Subsequent recognition of the Climax porphyry stock strengthens that belief. The relationship between the Climax porphyry stock and hydrothermal alteration is believed to be one of structural control.

Vanderwilt and King (1946)[23, 24] listed two important events that preceded hydrothermal alteration: 1—intrusion and crystallization of a quartz monzonite magma (Climax porphyry stock) and 2—injection of quartz monzonite (porphyry) dikes. The writers stated that the hydrothermal solutions penetrated the smallest fractures but did not discuss the solution channels and their origin.

Ore Channels: Closely spaced intersecting joints and related fractures provided the porosity and channels for the hydrothermal solutions. The long and complex history of the Paleozoic era followed by the Laramide period of mountain building provided ample time and opportunity for the jointing and fracturing. Injection of the Climax porphyry magma and its subsequent crystallization and cooling, with resulting contraction, would tend to produce more fractures in and close to the boundaries of the stock. A slight withdrawal of the magma during its fluid stage also could have been the cause of localized fracturing. Thus there was ample opportunity for development of joints and similar fractures to serve as channels for movement of hydrothermal solutions. Replacement of rock by hydrothermal solutions seems to have provided the space occupied by the quartz-molybdenite veinlets and also produced the quartz rock and rock alteration found everywhere between veinlets.

Movement of Hydrothermal Solutions: Above the 500 level plagioclase and biotite are rare in the Climax porphyry but below this level, particularly in the southwesterly half of the stock, these minerals become common with depth. Medium-grained quartz monzonite with much albite-oligoclase and biotite was encountered in diamond drillholes 1200 ft apart at depths 200 to 500 ft below the 500 level. Molybdenite concentration decreases and plagioclase and biotite increase in amount. The increase in plagioclase and biotite and decrease in molybdenite are regarded as indicative of less intense hydrothermal alteration. It is inferred that on these lower levels the rising hydrothermal solutions did not move as freely or in as great a volume through the interior part of the stock as through the northerly and northeasterly part. On the basis of these alteration effects it is concluded that the solutions in their upward course spread over and around the domal top of the stock altering and replacing the rock.

Although the greater movement of the hydrothermal solution was upward, sufficient spreading or lateral movement occurred which determined the horizontal extent of the overall rock alteration and greatest concentration in areas flanking the porphyry stock.

The quartz rock represents the greatest change brought about by hydrothermal solutions and therefore the locus of the more active and probably the greatest movement of hydrothermal solutions. It is logical to suppose that quartz replacement approaching 100 pct eventually sealed off the joint and fracture channels, forcing the flow of solutions and quartz replacement to encroach on the adjacent zone where the greatest concentration of molybdenite occurred. Under this interpretation, quartz replacement gradually advanced from the direction of quartz rock into the ore zone with its numerous molybdenite quartz veinlets. Evidence of such encroachment is the presence, particularly in proximity of the ore zone, of molybdenite bands and streaks with varying degrees of sharpness suggestive of partially replaced molybdenite-quartz veinlets in the quartz rock.

The uniform and complete replacement of the several rock types by fine-grained quartz rock and the widespread occurrence of molybdenite-quartz veinlets with associated quartz-orthoclase-sericite rock alteration between veinlets are indicative of great penetration by the altering solutions.

Rock alteration and concentration of related minerals occurred in relation to a central area. No evidence could be found that the solutions favored strong pre-mineral fracture zones within the area of hydrothermal alteration, except for a few scattered barren quartz veins in the marginal area. As a whole, lateral outward movement of the solutions from the central area was limited. On the other hand, the large volume of introduced material indicates that considerable movement of hydrothermal solutions occurred in the central area. It is assumed that the direction of movement was upward.

Sequence of Alteration: In the sequence given it is assumed that after the movement of hydrothermal solutions began, the intensity of rock alteration, including rock temperatures, increased to a maximum and then subsided. It is believed that mineralization and rock alteration were essentially contin-

uous and not in intermittent periods separated by long intervals of time. The basis for this belief is 1—uniformity of hydrothermal alteration, including the distribution of minerals; 2—the presence of elements such as molybdenum, tungsten, sulphur, and fluorine; 3—overlapping in age of many minerals that characterize the deposit; and 4—replacement origin of the molybdenite-quartz veinlets.

The earliest recognizable products of mineralization are the quartz rock representing a high degree of silicification and molybdenite-quartz veinlets with development of orthoclase predominating between the veins. An earlier phase of alteration with various mineral products can be inferred with some logic, but direct evidence is lacking.

The presence of what seem to be relict molybdenite-quartz veinlets in the quartz rock suggests a replacement or encroachment of the ore zone by quartz rock. However, the gradational changes from the quartz rock to the ore zone and from the ore zone farther outward suggest that when the solutions were bringing about complete silicification to form quartz rock, there occurred simultaneously the alteration which characterizes the ore zone and the surrounding marginal area. A corresponding temperature gradient decreasing from the central to marginal areas also is a logical supposition.

The quartz-pyrite-topaz veins, followed by sericite and topaz veinlets, represent the closing phase of alteration. Clay minerals are common in these late veins, and as alteration products in the areas between molybdenite-quartz veinlets.

The mineral associations are grouped as follows: 1—quartz rock representing essentially 100 pct silification; 2—quartz-molybdenite replacement veinlets with much secondary orthoclase-quartz and widespread pyrite, fluorite, sericite and clay-minerals in the areas between veins; 3—quartz-pyrite-topaz veinlets as fissure filling, with minor quantities of chalcopyrite, galena, sphalerite, monazite, cassiterite, hubnerite, and fluorite; and 4—sericite and clay minerals, chiefly kaolinite, in late veinlets without recognized wall rock alteration.

If a given horizontal level is considered, each group was being formed simultaneously. However, while rock temperatures were rising and intensity of hydrothermal activity was increasing the sericite and clay minerals probably formed first and exclusively in the extreme marginal areas. During this phase group 3 would advance onto group 4, group 2 onto group 3, and group 1 onto group 2. During the period of subsiding hydrothermal activity the encroachment of one group by the other would tend to be in the reverse order. Thus sericite and clay minerals formed early in the marginal areas and late in the veinlets in the more central areas.

Comparison with Porphyry Copper Deposits: The relationship of rock alteration at Climax to disseminated copper deposits, notably the deposits at Ely, Nev., and Bingham, Utah, was pointed out by Butler and Vanderwilt (1933).[11] Schwartz (1947)[24] lists four types of mineralization in *porphyry copper* deposits, three of which suggest similarity with hydrothermal alteration at Climax; 1—quartz-orthoclase, 2—quartz-sericite-pyrite, and 3—sericite-argillic. His fourth type, biotite, has not been found at Climax, although it is conceivable that the biotite found in a few deep diamond drillholes is secondary rather than primary, as described earlier.

At Climax orthoclase with quartz predominates over sericite-argillic alteration where the greatest concentration of molybdenite occurs. The closing phase of alteration was marked by quartz, pyrite, topaz, sericite and argillic minerals.

Other common relationships include: 1—proximity to a strong regional structure, 2—an intimate relationship of Tertiary porphyry intrusions ranging in composition from granite to monzonite and quartz monzonite, 3—permeability of the general host rock made possible by intersecting sets of closely-spaced joints, and 4—extensive hydrothermal alteration characterized by relatively uniform deposition of similar mineral suites over large areas.

These common features are of particular interest, since molybdenite is a characteristic accessory mineral of the *porphyry copper* deposits and copper is a minor accessory mineral in the Climax molybdenum deposit.

Acknowledgments

Geologic data and interpretations in this paper are the outcome of studies made on behalf of the Climax Molybdenum Co. during its program of exploration and development from 1929 to 1950. Full cooperation was given by all operating departments and administration of the company.

It is not possible to give individual credit to the many who contributed to the knowledge of Climax geology. David L. Evans and Julian W. Feiss deserve special mention. The authors also express appreciation to William J. Coulter for his continued interest and encouragement. Finally, the authors recognize that they must assume responsibility for the accuracy of the data presented and the logic of interpretations given.

References

[1] H. L. Brown and M. W. Hayward: Molybdenum Mining at Climax, Colo. *Engineering and Mining Journal* (1918) 105, pp. 905-908.

[2] L. S. F. Holland: Recent Development in Molybdenum. *Mining and Scientific Press* (1918) 117, p. 529.

[3] D. F. Haley: Molybdenite Operations at Climax, Colo. *Trans.* AIME (1919) 61, pp. 71-76.

[4] P. G. Worcester: Molybdenum Deposits of Colorado. Colorado Geol. Survey *Bull 14* (1919) pp. 91-94.

[5] B. S. Butler and J. W. Vanderwilt: The Climax Molybdenum Deposit of Colorado. *Proc.* Colorado Scientific Society (1931) 13, No. 10, pp. 309-353.

[6] Ref. 5, p. 342.

[7] L. W. Staples and C. W. Cook: A Microscopic Investigation of Molybdenite Ore, Climax, Colorado. *American Mineralogist* (1931) 16, pp. 1-17.

[8] C. W. Henderson: History and Production, Climax Molybdenum Deposit. U. S. Geol. Survey *Bull. 846-C* (1933) pp. 199-201.

[9] Charles E. Sears, Jr.: Hydrothermal Alteration and Mineralization in the Climax Molybdenum Deposit, Climax, Colorado. Unpublished doctoral dissertation, Colorado School of Mines, June 1952.

[10] F. H. Howell and H. T. Schassberger: Geology of the Climax Orebody, Climax, Colorado. Private report (1953) Geology Dept., Climax Molybdenum Co.

[11] B. S. Butler and John W. Vanderwilt: The Climax Molybdenum Deposit of Colorado. U. S. Geol. Survey *Bull. 846-C* (1933) pp. 199-237.

[12] Quentin D. Singewald: Geology and Ore Deposits of the Upper Blue River Area, Summit County, Colorado. U. S. Geol. Survey Bull. *970* (1951) p. 74.

[13] R. D. Crawford: Contributions to the Igneous Geology of Central Colorado. *American Journal of Science* (1924) 5th Series, 7, pp. 365-386.

[14] C. S. Behre, Jr.: Geology and Ore Deposits of the Eastern Leadville District, Colorado. U. S. Geol. Survey *Prof. Paper* 237 (1953).

[15] D. L. Evans and R. U. King: Private report, 1939.

[16] P. Billingsley and T. Lyons: Private report, 1918.

[17] D. V. Haines: A Spectrographic and Petrographic Study of the Ore Minerals at Climax, Colorado. An unpublished thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in January 1953, Department of Geology, The Pennsylvania State University.

[18] R. A. Ronzio, research metallurgist, Climax Molybdenum Co.: Personal communication, 1951.

[19] R. C. Mielenz, N. C. Schieltz, and M. E. King: Microscopical and X-Ray Diffraction Investigations of Rock Alteration. Private reports April 1952, July 1952, and February 1953.

[20] R. H. Sales and C. Meyer: Wall Rock Alteration at Butte, Montana. *Trans.* AIME (1948) 178, pp. 9-33.

[21] T. S. Lovering: The Geochemistry of Argillic and Related Types of Rock Alteration. *Colorado School of Mines Quarterly* (1950) 45, pp. 231-260.

[22] Warren R. Wagner: Personal communication, 1953.

[23] J. W. Vanderwilt and R. U. King: Geology of the Climax Ore Body. *Mining and Metallurgy* (1946) 27, No. 474, pp. 291-304.

[24] Ref. 23, pp. 299-302.

[25] G. M. Schwartz: Hydrothermal Alteration in the "Porphyry Copper" Deposits. *Economic Geology* (1947) 47, pp. 319-352.

Chuquicamata Develops Better Method to Evaluate Core Drill Sludge Samples

by Glenn C. Waterman

THE diamond drill is a very important tool in exploration and development testing and its use is increasing. In almost all cases results of diamond drilling are analyzed on the basis of grade and tons. A proper evaluation of core and sludge assays is important if drilling results are to be acceptable as a basis for geologic and engineering appraisal. The relatively wide variation in assay averages as calculated by various well-known combining methods indicates that the engineering choice of a method may affect the outcome of the drilling in terms of ore and waste.

The problem of combining assay results from core and sludge samples has been discussed many times in conference and in the literature.[1-4] Most writers agree that the field of disagreement in methods is large and that the engineer on the job must consider features unique to his drilling, pick one of several combining methods, and depart from the rules when abnormal results come in. All the discussion to date can be summed up by the admission that as yet there is no fairly simple, generally acceptable combining method that is practicable over a wide range of drilling conditions, ground conditions, and ore occurrence.

The combining problem is important in evaluating drilling results at Chuquicamata. Recently a reappraisal has been made of recovery variables and their effect on assays, with the result that a new combining method is offered which fits average drilling conditions and is mathematically reasonable. It is simple in application, fundamentally correct, and an improvement over most combining methods.

At Chuquicamata diamond drillholes are used to outline the grade and position of blocks of normal and marginal grade oxide, mixed, and sulphide ore. Most holes penetrate all classes of material (and waste), and it is important for mining programs as well as ore reserves to know almost precisely the soluble and insoluble copper content of mineralized ground. At present three classes of ore are mined and treated differently. For an orderly sequence of mining operations which can provide regular daily tonnages of all three ore types and keep grade at certain levels with minimum variation, ore type and its grade must be predicted. Diamond drilling plus geologic mapping and bench sampling are tools for prediction. And drilling data are largely used to calculate grade of material more than a few meters away from bench faces.

G. C. WATERMAN, Member AIME, is Chief Geologist, Chile Exploration Co., Chuquicamata, Chile.

Discussion on this paper, TP 3965A, may be sent (2 copies) to AIME before March 3, 1955. Manuscript, Oct. 20, 1954. Chicago Meeting, February 1955.

The orebody at Chuquicamata[5] is criss-crossed by millions of barren or mineralized weak to fairly strong slips and fault fissures. Mineralization is diverse and encompasses many quartz and oxide or sulphide-bearing copper veins, as well as seams and disseminated grains. Copper occurs in oxide or sulphide minerals or mixtures of these two mineral types. Rock conditions vary from intensely sericitized (soft and porous) through clay-altered ground to almost fresh granodiorite. The result is an orebody which offers many obstacles to good and consistent core recovery in diamond drilling. Recovery varies considerably in the several alteration zones, the various types of oxide and sulphide ores, and the position and inclination of the drillhole within the complex fracture pattern. As core recovery drops sludge samples must be used with core samples to calculate grade.

Many years of drilling at Chuquicamata indicate that in good grade oxide zones and in the sulphide areas core recovery is good and the ground uniformly mineralized. Moderate loss of core, therefore, does not markedly affect grade calculations based on core assays. An early core-sludge combining method used core assays at face value as indicating grade down to 50 pct core recovery, but below this recovery percentage sludge samples were used and weighted according to the standard Longyear chart. This method apparently did not introduce serious errors, but it abruptly used sludge assays with high weighting factors representing 100 pct return irrespective of actual percentage of sludge recovered.

Recent drilling activities have been directed toward outlining the marginal ore areas. The nonuniform mineralization and generally poorer core recovery in such ground indicated that a more exact core-sludge combining method was required to equate wide differences between core and sludge assays and recovery. In fringe ore areas at Chuquicamata core recovery averages about 50 pct, from a minimum of 10 to 15 pct to a maximum of 100 pct. Sludge recovery is likewise variable and averages perhaps 80 pct even though holes are cemented as water return falls off.

In a homogeneously mineralized area cut by many slips and faults, with hard and soft ribs, loss of core is loss of ground which has a grade similar to that of core recovered, and core assays approximate true grade. In this case sludge samples need not be used. However, it would be unusual to know beforehand that an area is uniformly mineralized, and in fact this condition is probably uncommon. Generally the distribution of valuable minerals in the ground does not exactly compare with their recoverability in core. Thus, in the usual case, loss of core decreases the

validity of the assay of recovered core as representative of the entire run.

Core recovery depends on the nature of the ground being drilled, the type of equipment used, the skill of the operating personnel, and the cost that management will bear to improve core recovery technique. In a normal drilling job, there are features of daily drill operation which inhibit excellent sludge recovery. Perfect recovery can be obtained only when there is complete water return, complete settling of all sludge pumped out, complete flushing of the drillhole after each run, and no pollution by caving or rod abrasion. Unless the job is closely supervised it is extremely rare to find drillers who will clean out each run conscientiously. It is a problem to settle and weigh all sludge. And it is uncommon in well-mineralized ground, which often as not is well fractured, to obtain complete water return. To ascertain the percentage of return, water pumped in and recovered must be measured constantly. When core recovery is poor, it is usually because the ground is soft or *broken*, often resulting in sludge pollution by caving. All in all, when poor-coring ground is encountered sludge return is usually far from uniform. As sludge recovery departs from the theoretical, sludge assays are increasingly unreliable as indicators of true grade.

Core and sludge assays should be combined in a realistic fashion whenever core recovery is less than 100 pct. A combining method should show the higher or lower grade character of all unrecovered core, as derived from sludge samples, as long as the reliability of the sludge assay is not less than that of the core assay at any core recovery percentage.

The basic methods of core-sludge evaluation involve combining assays by theoretical or recovered weights or volumes. In the weight method the weighting to assign core and sludge assays is proportional to weight of recovered core and sludge. The fundamental assumption is that reliability of sludge and core is proportional to percentage recovered. In the volume method the theoretical volumes represented by core and sludge determine their weighting; the fundamental assumption is that at any sludge recovery percentage the sludge recovered is representative of all the sludge plus the ground-up core. Generally the reliability of the sludge sample is the important unknown, introducing variations in calculated grades as determined by the several methods.

On many drill jobs core assays are considered representative of the grade of an entire run down to 90, 70, or sometimes 50 pct recovery. Below this recovery core-sludge samples are combined on the basis of theoretical or recovered weights or volumes to determine the grade of the run. This is an illogical method. It assumes that immediately below some artificially established core recovery percentage the core suddenly becomes an unrepresentative sample and must be combined with a sludge sample which is usually given very high weighting, even though the sludge sample was considered worthless at a slightly higher core-recovery percentage. Consider the following examples. In example 1, down to 95 pct core recovery the core sample is considered representative of the entire run. Below 95 pct core recovery, sludge-core samples are combined according to theoretical volumes.

In example 2, down to 80 pct core recovery the core sample is considered representative of the entire run. Below 80 pct core recovery, the core-sludge samples are combined according to the theoretical volumes.

Example 1	Weighting Percentages							
Core Recovery, Pct	NX		BX		AX		EX	
	Core	Sludge	Core	Sludge	Core	Sludge	Core	Sludge
100	100	0	100	0	100	0	100	0
95	100	0	100	0	100	0	100	0
94	48	52	45	55	34	66	33	67
90	46	54	43	57	32	68	32	68
85	43	57	41	59	31	69	30	70

Example 2	Weighting Percentages							
Core Recovery, Pct	NX		BX		AX		EX	
	Core	Sludge	Core	Sludge	Core	Sludge	Core	Sludge
100	100	0	100	0	100	0	100	0
90	100	0	100	0	100	0	100	0
80	100	0	100	0	100	0	100	0
79	40	60	38	62	28	72	28	72
75	38	62	36	64	27	73	27	73

In the first example, at BX size, core sample weighting is decreased from 100 to 45 pct when core recovery drops from 95 to 94 pct, and it is decreased only 2 pct more for an additional 4 pct decrease in recovery. In the second example the weighting assigned core is 100 to 80 pct recovery; then a drop of only 1 pct in recovery to 79 pct drops the core weighting from 100 to 38 pct. A further 4 pct decrease in recovery only decreases core weighting 2 pct. This is obviously poor practice, for at arbitrary limits sludge samples are abruptly given predominant weighting and usually the sludge recovery is not considered in assigning the weighting. Core sample weighting is markedly decreased as core recovery drops, and it is no more than logical that sludge samples should be given less weighting when sludge recovery drops.

If Longyear charts are used to determine weighting percentages when sludge recovery is less than 100 pct, as is often the case, then core weighting is being reduced as its recovery drops but sludge weighting is not affected. If sludge is weighted according to ratio of core and sludge recovered the method is improved; nonetheless sludge abruptly receives important weighting at an arbitrary point.

On drilling jobs where grade is important, drill core should be of sufficient size with respect to drillhole spacing to insure that with 100 pct core recovery the assay of the core is accepted as true grade. This means sludge assays should only be used to determine the grade to assign unrecovered core so that when combined with a core assay the resultant grade approximates the grade that would have been obtained had all the core been recovered. If the assay from 100 pct recovered core is combined with sludge assays, then the engineer has adopted the premise that the size of the core (within the grid of drill layout) is too small to give a representative sample of the ground being tested. These two cases require different treatment in establishing a combining method, for in the first case the core gives a representative sample and in the second it does not. The combining method to be described below deals only with the first case, when the core at 100 pct recovery is considered to give a true grade of the ground drilled. This is the situation on most drilling jobs.

On the above basis there is a two-fold problem in weighting core-sludge samples: 1—use of sludge assay to determine the grade of unrecovered core and to combine this with the core assay, and 2—weighting percentages to assign core and sludge

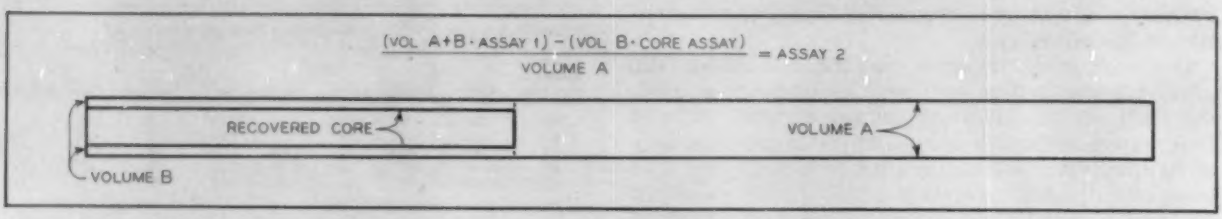


Fig. 1—Diagrammatic section of drillhole. Volume *A* is ground-up core and sludge peripheral to it. Volume *B* is sludge peripheral to recovered core. Assay 1 is sludge assay from laboratory. Assay 2 is adjusted sludge assay, or grade of ground-up core.

assays as the percentage of recovery is less, or (in sludge) greater than the theoretical.

If 100 pct core is considered a representative sample, then any percent of core recovered is a truly representative sample of that percentage of the run. Thus at 10 pct core recovery, for instance, the assay of this core should receive at least a 10 pct weight when combined with sludge samples. If the sludge recovery is perfect, then the core should receive 10 pct and the sludge 90 pct weighting. This means a core sample should receive at least a weighting percentage equal to its recovery percentage and that the sludge sample should receive a maximum weighting of 100 pct minus weighting assigned the core sample. The sludge sample is thus weighted to correspond to the unrecovered core and the sludge assay must be adjusted so it represents only the lost core.

At 100 pct core and sludge recovery, the in-place volumes of core and sludge in BX and NX holes are approximately equal. AX holes show a core-sludge volume ratio of 36 to 54 and EX holes a ratio of 35.5 to 64.5. If at any core size 100 pct core gives a representative sample then in all cases the theoretical sludge volume is equal to or greater than the core volume. This suggests the sludge peripheral to core should have a similar grade, and at 100 pct sludge return it should have an assay similar to that of the core, as it contains an equal or greater amount of material and the smaller or equal core volume is considered to yield a representative sample. It can be considered, therefore, that the sludge sample is made up of two parts: 1—a percentage which is peripheral to recovered core and which has a grade similar to the core grade, and 2—a percentage made up of unrecovered core and material peripheral to it, both of which have similar grade.

It is desired to combine the assay of the recovered core with a grade of sludge which corresponds to the grade of the unrecovered core. To have the sludge grade represent the grade of unrecovered core it is necessary to deduct from the assay of all the sludge a total volume which represents the sludge peripheral to recovered core and assign to this portion of the sludge a grade equal to the core grade. It can then be considered that the remaining sludge, with its new adjusted grade, is equal to the grade of the unrecovered core because it is made up of the lost core and sludge peripheral to it, both of which have similar grade.

The formula in Fig. 1 shows the method of adjusting the sludge grade as outlined above. The step outlined requires that as sludge assays come in from the laboratory they must be adjusted to give a grade corresponding to the presumed grade of the lost core. In as much as the amount of adjustment varies according to the core size, the percent of core recovery, and the ratio between the core and sludge assay, a simple adjustment is impossible. On the basis of theoretical volumes of core-sludge for BX holes and the recovery and ratio variations, the chart in Fig. 2 has been constructed. This gives adjusted sludge grades for any core recovery and most sludge/core assay ratios. Similar charts can be constructed for other hole sizes. If the adjusted sludge grade is to be determined by use of the chart, Fig. 2, laboratory assays, percent of core recovery, and ratio of sludge/core assay must be known. Core recovery percentage is found by measurement of core length. The ratio figure is obtained by dividing the core assay into the sludge assay.

Percentages of core recovery are plotted along the upper left edge of the chart. The adjusted sludge assay is found by tracing the vertical core recovery percentage line to its intersection with the curving sludge/core ratio line. This point is carried horizontally to the right to an intersection with the diagonal line representing the sludge assay. This new intersection is carried up vertically to the top of the chart to figures representing the adjusted sludge grades.

If the intersection of the core recovery line and the sludge/core ratio curve is at the top line of the chart, the adjusted sludge assay is zero. This means all the valuable material represented in the sludge assay can be attributed to the sludge peripheral to recovered core. In certain cases the intersection point will fall above the top line of the chart. These cases represent an impossible situation, i.e., the sludge assay is too low to permit a calculation of an adjusted sludge grade, or stated differently, there is not enough valuable material reported in the sludge assay to satisfy the condition that the grade of sludge peripheral to recovered core is the same grade as that core. This situation can be caused by several variables: 1—The sludge peripheral to recovered core is lower grade than that core. 2—An important percentage of the valuable mineral in the sludge has been lost. 3—The sludge sample, polluted by lower-grade material, is not representative.

When the intersection point falls on or immediately above the top line of the chart, Fig. 2, the figure 0 is used for the adjusted sludge grade. When the intersection rises a greater distance above the top the sludge sample is eliminated as wholly unreliable and the assay of the recovered core is used as the best figure available to represent the grade of the run. The chart mathematically eliminates sludge samples that are worthless even though sludge recovery percentage indicates the sample should be good. These cases are not rare in caving ground where water return falls off, because often the loss of sludge and valuable mineral from the interval being drilled is made up by pollution from higher in the hole. This elimination feature of the chart, Fig. 2, is of great value because it shows up unreliable sludges which otherwise might be combined with good core assays to give wholly erroneous combined grades.

At Chuquicamata, where assay reports show soluble, insoluble, and total copper, the oxide ore

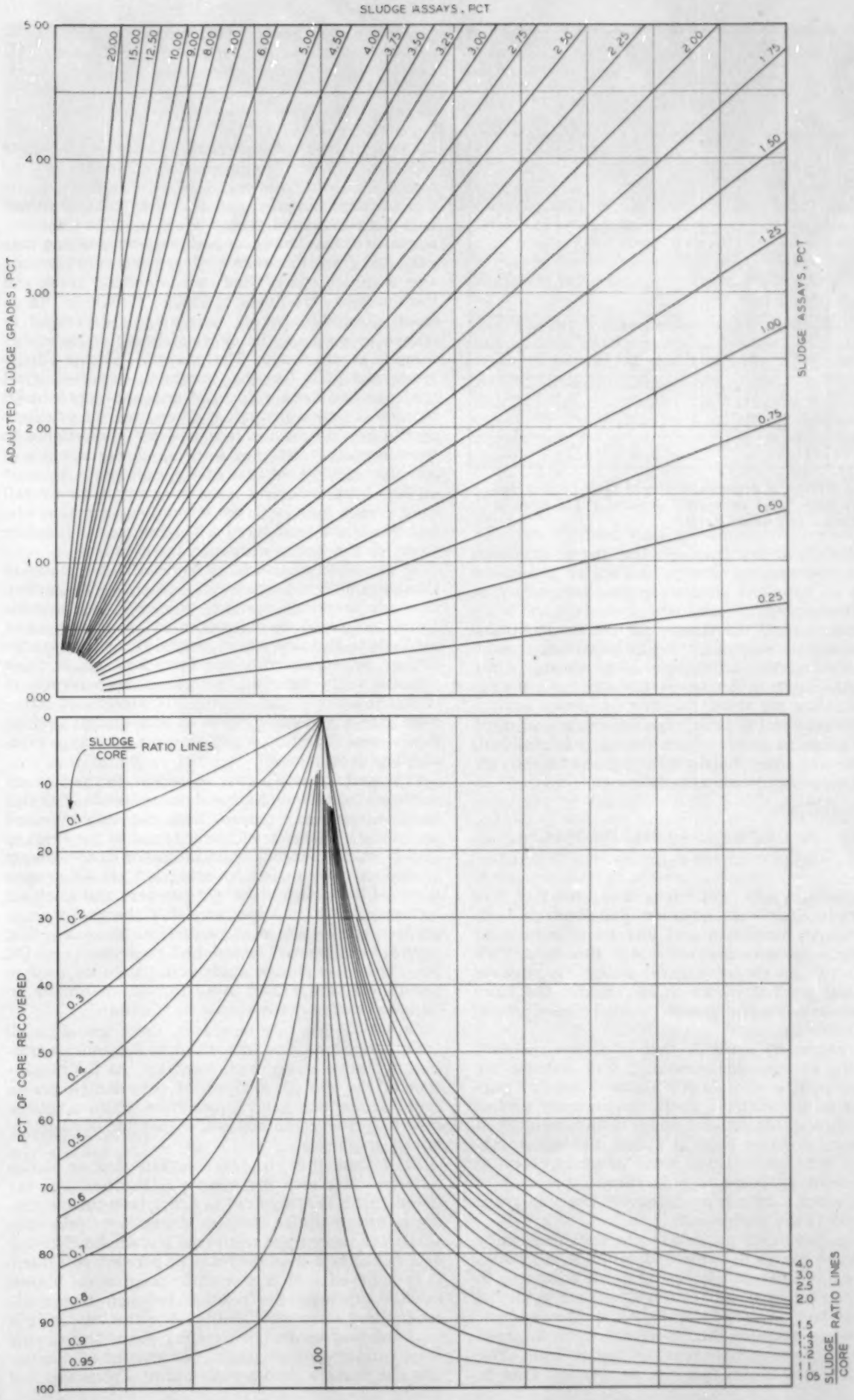


Fig. 2—Charts for adjusting sludge assays for BX holes, Chuquicamata, 1954.

CORE RECOVERED, PCT	CENTIMETERS RECOVERED	SLUDGE RECOVERED, PCT											
		100	98	96	94	92	90	88	86	84	82	80	78
100	150	100 0											
98	147	98 2	100 0										
96	144	96 4	98 2	100 0									
94	141	94 6	96 4	98 2	100 0								
92	138	92 8	94 6	96 4	98 2	100 0							
90	135	90 10	92 8	94 6	96 4	98 2	100 0						
88	132	88 12	90 10	92 8	94 6	96 4	98 2	100 0					
86	129	86 14	88 12	90 10	92 8	94 6	96 4	98 2	100 0				
84	126	84 16	86 14	88 12	90 10	92 8	94 6	96 4	98 2	100 0			
82	123	82 18	84 16	86 14	88 12	90 10	92 8	94 6	96 4	98 2	100 0		
80	120	80 20	82 18	84 16	86 14	87 13	89 11	91 9	93 7	96 4	98 2	100 0	

Fig. 3—Portion of geometric combining chart for core and sludge assays based on recovery percentages. Top figure in each box is core weight factor.

normally shows low insoluble and the sulphide ore low soluble copper. Assay results for these low figures on core and sludge samples normally give good checks, but because the percentage variation may appear high, the sludge/core ratios may show "an impossible situation." It has been found much better to use the two highest assay figures of the three submitted to determine the sludge/core ratio needed to use the chart, Fig. 2.

In the case of 100 pct sludge return, the adjusted sludge grade as derived from the chart is combined with the core assay to determine a grade for the run. This simple calculation is as follows:

Combined Grade =

$$\frac{[CA \cdot \text{Pct } CR] + [ASA \cdot (100 \text{ Pct} - \text{Pct } CR)]}{100 \text{ Pct}}$$

CA is core assay. Pct *CR* is the percent of core recovered. *ASA* is the adjusted sludge assay.

The above discussion and method of combining core-sludge samples is applicable to situations when there is 100 pct recovery of the sludge. It provides a starting point from which to consider the more usual situations when sludge return is less or more than theoretical.

It is extremely unlikely that as sludge recovery decreases the amount recovered will contain the same proportion of valuable (usually heavy) particles as would be found in the theoretically perfect return. As water is lost and sludge return diminishes, the heavy particles tend to follow the water into areas of reduced velocity. Thus in many cases, as sludge recovery percentage decreases, the assay of the recovered sludge is progressively lower in grade compared to the sludge lost.

At Chuquicamata an incomplete statistical study of drillhole assays in oxide and sulphide ore shows that there is a decrease in sludge grade compared to core grade (at excellent recovery) as soon as sludge recovery drops below 100 pct. As sludge recovery continues to decrease the percentage drop in grade is less but the assays are less and less reliable. The tabulation also shows that the percentage drop in sulphide ore is greater than in oxide ore. This is reasonable, as the specific gravity of sulphide particles is higher, and the increasing amount of material which is lost as sludge recovery drops contains larger percentages of the heavier and much more cupriferous particles.

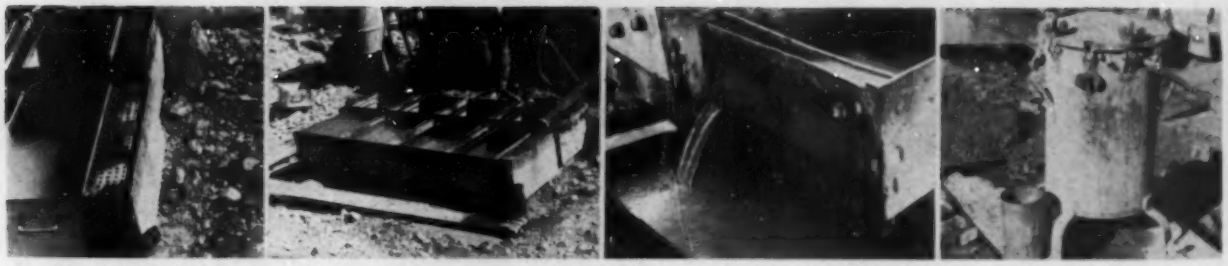
Statistical evidence that sludge samples lose grade at below 100 pct recovery when compared to core samples indicates that calculations of combined grade using sludge samples with less than 100 pct return will yield combined grades which are low. The importance of this *low combined grade* as affecting tonnage and grade calculations depends on the percentage of sludge assays used in establishing grade and the average percentage of sludge recovered. In as much as sludge sample weighting is decreased as recovery drops off, the effect of lower grade sludge samples is minimized. That a combined core-sludge grade is a little less than might be expected if all the core had been recovered and the grade based thereon is a good feature; it gives a margin of safety on the low side which is somewhat proportional to the uncertainty attached to using sludge samples at less than perfect return. At Chuquicamata, because of the above factors, it is estimated that the overall drill grades may be 1 pct lower than actual grade, but this is not considered a bad feature. It is better to err on the low side than on the high side.

A complete statistical study could be made at Chuquicamata to predict a probable percentage drop in grade as sludge recovery decreases, and this information could be incorporated in sludge assay evaluation. But this would assume that average conditions were uniformly operative and would mask the markedly different variations encountered in different parts of the orebody. It would also introduce into a general method of core-sludge evaluation a local condition which would not be applicable at other properties.

It is quite possible that at certain properties reliable statistics would show definite trends of sludge grade as recovery dropped. Such data could be used to modify a sludge grade prior to use of the chart in Fig. 2. If, for instance, data indicated that at 90 pct sludge recovery the sludge assay is 5 pct lower than it would have been at 100 pct recovery and at 80 pct recovery it is 8 pct lower, etc., then the sludge assay grade could be increased to simulate the grade that would have been obtained had recovery been 100 pct. This new sludge grade could then be used to calculate a sludge/core assay ratio to determine an adjusted sludge grade by use of the chart.

On a drill job in a new area, there would be no information available with which to determine variation in sludge assays with recovery. At the conclusion of the job an analysis of core-sludge grades could be made to yield information which might be used to correct combined grades that had been determined previously.

All information strongly suggests that as sludge recovery decreases the sample is less and less reliable. If this is recognized as a fact, then the weighting to assign sludge samples should not be in proportion to percentage recovered but should decrease at a faster rate than decrease in percentage return. It is believed that a geometric progression almost exactly expresses the relation between sludge recovery and sample reliability. For this reason it is assumed that as sludge recovery drops the sample loses validity geometrically. No amount of calculation can make a good sample out of a poor one, but



Figs. 4-7 (reading left to right). Fig. 4—Chuquicamata sludge splitter consists of removable top plate with ¼-in. holes and a lower plate with ⅛-in. holes which discharges into the sludge box or into troughs leading outside the box. Fig. 5—View of sludge box showing weirs and sludge splitter. Fig. 6—View of discharge end of sludge box showing decanting plugs, removable bottom plate, and metal box used to catch sludge and cloudy water. Fig. 7—Vacuum filter used for drying sludge. At left is metal tube used for transport and measurement of dried sludge.

the poorer sample can be given less weighting and thus used in proportion to its reliability in establishing a combined grade.

One other factor of importance is the reliability of core and sludge samples at similar recovery percentages. If sludge samples at 100 pct return are disregarded at 100 pct core recovery, it follows that the sludge sample is considered less reliable. Thus, in cases when sludge recovery is less than core recovery, the former samples should be disregarded for grade determination. This means that a core sample representing 50 pct recovery is closer to the true grade of the run than a sludge sample of 40 pct recovery, and to combine the sludge sample with the more reliable core sample is to introduce serious error in the calculated grade of the run.

Core-sludge combining factors have been calculated for any combination of core-sludge recovery on the basis of several logical assumptions: 1—The sludge sample loses reliability geometrically as sludge recovery drops. 2—The sludge sample should not be used if the percentage of sludge return is less than the percentage of core recovered. 3—A core sample should receive a weighting at least equal to the percentage of core recovery. The geometric chart, Fig. 3, for combining core and sludge assays based on recovery percentages is derived from the geometric progression formula $L = AR^{(N-1)}$, where L is the last term of progression, A the first term of progression, R the geometric ratio, and N the number of terms in progression. The chart in Fig. 3 gives the core recovery in terms of percentage and centimeters recovered on the left side and percentage of sludge recovered across the top. At any given core recovery and 100 pct sludge recovery the weighting factors are: 1—core pct recovery, and 2—sludge 100 —core, recovery percent. As sludge recovery drops off sludge weighting is decreased geometrically to the point where core and sludge recovery percentages are equal. Below this percent of sludge recovery the sludge sample is considered less reliable than the core sample and is not used.

To use the chart in Fig. 3 it is necessary that percentage of sludge recovered be known. On many drill jobs, sludge settling is by means of barrels wherein practically all the sludge that comes out of a hole is recovered. A measurement of the sludge volume or weight will give the percentage recovered when core recovery is known.

At Chuquicamata practical considerations in drilling from mining benches with limited room and usually a short allotted drilling time preclude the use of a complex sludge-settling system. To facilitate speedy, accurate sludge recovery, metal sludge boxes having sludge splitters at the upper end are used, Figs. 4, 5, and 6. These boxes have overflow weirs and decanting plugs, and a box is able to hold all the water and sludge from a standard 1.5 meter run at the predetermined sludge split. Settling time is provided by use of several boxes. Clear water is decanted and remaining cloudy water and sludge drawn off, dried in vacuum filters at the drill rig, and placed in standard metal tubes open at one end. A vacuum filter is shown in Fig. 7.

To determine the percentage of sludge recovered, the height of sludge in each metal tube is measured in centimeters, the length of core recovered is measured, and these two measurements are used

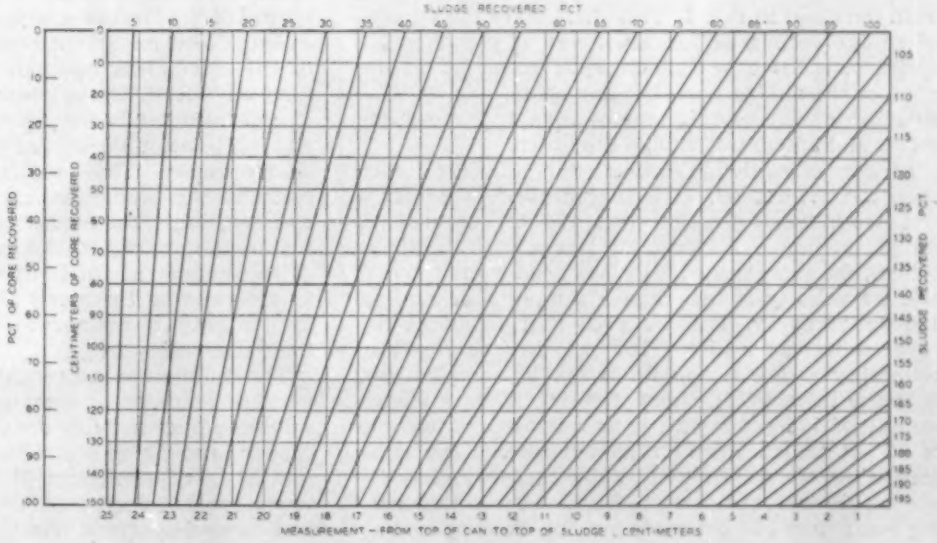

SLUDGE RECOVERED PCT
PCT OF CORE RECOVERED
CENTIMETERS OF CORE RECOVERED
SLUDGE RECOVERED PCT
MEASUREMENT – FROM TOP OF CAN TO TOP OF SLUDGE, CENTIMETERS

Fig. 8—Chart for determining percent of sludge recovered, BX holes. 1/3 split discarded; 1.5 meter holes. Sludge cans are of 6-in. diam and 10-in. depth.

The Core-Sludge Combining Method

Primary Data:

1—BX core, standard 1.5 meter runs.
2—Core recovery 35 pct (by measurement of core length).
3—Sludge recovery 80 pct (by measurement of height of sludge in metal can and use of chart in Fig. 8).
4—Core assay: 2.50 pct insoluble cu., 0.50 pct soluble cu.
5—Sludge assay: 1.90 pct insoluble, 0.75 pct soluble copper.

Step 1. Determination Adjusted Sludge Assays

For the insoluble copper in the assays the ratio of sludge assay/core assay is $\frac{1.90}{2.50}$ or 0.76.

For the soluble copper in the assays the sludge/core ratio is $\frac{0.75}{0.50}$ or 1.50.

By use of Fig. 2 for insoluble copper, the intersection of the 35 pct core recovery line with the 0.76 ratio curve is carried horizontally to the sludge assay grade of 1.90 pct. Vertically above this intersection is the adjusted sludge insoluble grade of 1.77 pct.

By use of Fig. 2 for soluble copper, the 35 pct core recovery line is traced downward to its intersection with the 1.5 ratio curve, this intersection is carried to the right to the sludge assay curve of 0.75 pct, and the adjusted sludge soluble grade of 0.81 pct is found vertically below.

Step 2. Determination of Core-Sludge Weighting Factors

By use of Fig. 3, the 80 pct sludge-recovery block is traced down to its intersection with the 34 or 36 pct core recovery block and the 35 pct core recovery percentage visually interpolated. The weighting factors are 48.5 pct for core and 51.5 pct for sludge.

Step 3. Calculation of Combined Grade

The core assays of 2.50 pct insoluble and 0.50 pct soluble are given a weighting of 48.5 pct and the adjusted sludge assays of 1.77 pct insoluble and 0.81 pct soluble, a weighting of 51.5 pct; the combined grade for the 1.5 meter run is 2.12 pct insoluble and 0.66 pct soluble copper.

with the chart in Fig. 8. This chart gives the percent of sludge recovered for BX holes at standard 1.5 meter runs for a 1/3 sludge split discarded at the head of the sludge box. Similar charts can be constructed for any hole size, method of sludge measurement, and amount of sludge discarded.

In some cases sludge recovery percentage is higher than the theoretical. It is inaccurate to consider a weighting factor greater than 100 pct because as sample volume is increasingly larger than the theoretical, the sample obviously has been contaminated and its validity is less than a sample representing 100 pct recovery. It is believed that as sludge recovered increases above 100 pct the samples lose reliability at the same rate as do the samples that decrease in recovery below 100 pct. Thus a sludge sample of 120 pct return is as reliable as a sample of 80 pct return and both should receive the same weighting. To determine a sludge recovery percentage usable with the chart in Fig. 3 for samples having more than 100 pct recovery, the excess percentage over 100 is subtracted from 100 and the new figure used to represent the sludge recovery.

The Chuquicamata core-sludge combining method is very simple to use. The core recovery and sludge recovery percentages are determined as described above. When the assays come in, the sludge/core ratio is calculated and an adjusted sludge grade found by use of the chart in Fig. 2. This adjusted assay is combined with the core assay on the basis of core-sludge recoveries, by use of the chart in Fig. 3. A typical example, left, illustrates this system.

To simplify the calculations as well as leave a permanent record of all data, a form has been developed on which are placed all recovery percentages, assay grades, ratio numbers, adjusted grades, weighting factors and combined grade. With this form and an automatic calculator having cumulative multiplication the calculations are easy.

For purposes of comparing the Chuquicamata combining method with several well-known methods, two recent oxide and sulphide ore runs at Chuquicamata are given in Table I. Table II shows the variations in combined assays as calculated by the several methods.

Table I. Comparison of Data for Two Ores Run at Chuquicamata

Core Recovered, Pct	Core Assay		Sludge Recovered, Pct	Sludge Assay	
	Soluble	Insoluble		Soluble	Insoluble
OXIDE ORE, 1.5 Meter Runs					
44	0.46	0.39	81	0.72	0.13
50	1.12	0.35	67	0.72	0.10
58	2.42	0.21	95	1.35	0.10
57	0.95	0.22	102	1.31	0.10
61	0.30	0.23	73	0.95	0.11
80	1.51	0.23	48	0.98	0.12
64	1.18	0.13	115	1.05	0.12
63	1.24	0.28	91	1.07	0.10
Average	1.15	0.26		1.02	0.10
SULPHIDE ORE, 1.5 Meter Runs					
33	0.05	0.99	54	0.08	1.02
17	0.13	1.44	50	0.12	0.97
24	0.18	2.00	52	0.14	0.99
32	0.01	1.74	90	0.16	1.10
60	0.09	1.90	103	0.11	1.85
Average	0.09	1.61		0.12	1.19

In a comparison of the combined grades and averages shown in Table II with the original assay data in Table I, it is pertinent that the spread of 0.06 soluble and 0.06 insoluble between the various combined averages for oxide ore is almost 50 pct of the spread in the original assays as shown by a numerical average. This important variation indicates that some of the calculation methods must be poor if others have any merit. The sulphide ore run shows a spread of 0.42 insoluble in the average of the original assays and 0.27 insoluble in the various combined core-sludge grades. This large spread, from an average close to the sludge average to close to the core average, indicates combining methods lean toward the sludge or toward the core assays, and that one of the important fundamental questions to answer in determining the merit of a combining method is the validity it assigns to core-sludge samples as their recoveries drop.

The maximum percentage spread between the various averages of combined grade is 5.4 pct for soluble copper in oxide ore and 20.0 pct for insoluble copper in sulphide ore. Often this amount of variation in assay averages will make the difference between ore and waste. Certainly the combining problem is an important one if the accuracy of pencil

Table II. Comparison of Several Combining Methods

Sum of Core and Sludge Assays Divided by 2		Longyear BX Chart, Assuming 100 Pct Sludge Return		Core and Sludge Recovered, Pct*		Core and Sludge Recovered, Pct, with Exception, See Footnote**		Using Moehlman Charts		Core Assays at 100 Pct Wt Down to 80 Pct Core Recovery†		Core Assays at 100 Pct Wt Down to 80 Pct Core Recovery‡		Chuquicamata Method	
Soluble	Insol.	Soluble	Insol.	Soluble	Insol.	Soluble	Insol.	Soluble	Insol.	Soluble	Insol.	Soluble	Insol.	Soluble	Insol.
OXIDE ORE															
0.59	0.26	0.66	0.19	0.63	0.22	0.63	0.22	0.66	0.20	0.66	0.19	0.63	0.22	0.62	0.23
0.92	0.22	0.82	0.16	0.89	0.21	1.12	0.35	0.85	0.18	0.82	0.16	0.89	0.21	1.12	0.35
1.89	0.15	1.64	0.13	1.75	0.14	1.75	0.14	1.65	0.13	1.65	0.13	1.76	0.14	1.72	0.15
1.13	0.16	1.21	0.13	1.18	0.14	1.18	0.14	1.21	0.13	1.21	0.13	1.18	0.14	1.21	0.13
0.62	0.17	0.76	0.15	0.65	0.16	0.30	0.23	0.72	0.15	0.76	0.15	0.65	0.16	0.46	0.20
1.25	0.17	1.18	0.16	1.31	0.19	1.51	0.23	1.28	0.18	1.51	0.23	1.51	0.23	1.51	0.23
1.12	0.12	1.09	0.12	1.10	0.12	1.10	0.12	1.09	0.12	1.09	0.12	1.10	0.12	1.12	0.13
1.15	0.19	1.14	0.17	1.15	0.18	1.15	0.18	1.14	0.18	1.24	0.28	1.24	0.28	1.24	0.28
1.08 pct	0.18 pct	1.06 pct	0.15 pct	1.06 pct	0.17 pct	1.09 pct	0.20 pct	1.08 pct	0.16 pct	1.12 pct	0.17 pct	1.13 pct	0.19 pct	1.12 pct	0.21 pct
SULPHIDE ORE															
0.07	1.00	0.08	1.02	0.07	1.01	0.05	0.99	0.07	1.01	0.08	1.02	0.07	1.01	0.06	1.01
0.12	1.21	0.12	1.01	0.12	1.09	0.13	1.44	0.12	1.04	0.12	1.01	0.12	1.09	0.12	1.17
0.16	1.50	0.14	1.11	0.15	1.30	0.18	2.00	0.15	1.19	0.14	1.11	0.15	1.30	0.15	1.51
0.08	1.42	0.14	1.20	0.12	1.27	0.12	1.27	0.13	1.21	0.14	1.20	0.12	1.27	0.16	1.36
0.10	1.87	0.10	1.86	0.10	1.87	0.10	1.87	0.10	1.86	0.10	1.87	0.10	1.87	0.10	1.85
0.11 pct	1.40 pct	0.12 pct	1.24 pct	0.11 pct	1.31 pct	0.12 pct	1.51 pct	0.11 pct	1.26 pct	0.12 pct	1.24 pct	0.11 pct	1.31 pct	0.12 pct	1.38 pct

* Combined assay = $\frac{\text{Core Assay x Pct Core Recovery + Sludge Assay x Pct Sludge Recovery}}{\text{Pct Core Recovery + Pct Sludge Recovery}}$

** Excepting sludge assays not used if percent sludge recovered in below 80 pct.

† Below 80 pct, assays combined a/c Longyear chart.

‡ Below 80 pct, assays combined a/c percent recovered.

work at the conclusion of a large expenditure may have as much to do with the determination of ore and waste as the data supplied by many drillholes.

It is believed that the Chuquicamata method of combining core-sludge assays has several features making it superior to most well-known methods.

1—The system is applicable over a wide range of core size, core and sludge recovery percentages, and variable drilling conditions.

2—The method does not require artificial, variable assumptions by engineering personnel as to limits of validity of core-sludge samples.

3—Core sludge samples are combined whenever core recovery drops below 100 pct, but sludge weighting is low when core recovery is high. Pertinent, valid sludge assay data are used at high core recovery rather than discarded because of the high core recovery.

4—Core recovered is considered to give a valid sample for at least the percent of the run the core represents rather than being discounted when sludge recovery is high.

5—Impossible sludge samples are automatically eliminated as wholly unreliable, even though a high percentage of sludge recovered suggests a sample may be a good one.

6—The sludge assay is adjusted to subtract from it a volume and grade equal to the sludge peripheral to recovered core. The adjusted sludge grade thus correctly represents only the grade of ground-up core and sludge peripheral to it.

7—As sludge recovery falls off the reliability of the sample decreases geometrically and the sample is given less weighting.

8—When the percentage of sludge recovered is less than the percent of core recovered the sludge assay is not used. The fluctuating variables which make for poor sludge return affect the sludge grade to such an important extent that greater error is introduced into grade calculations by combining a poor sludge with a more valid core sample than occurs when the better core sample is used alone as representing grade of the entire run.

9—The method does not require engineering opinion as to limit of local applicability.

Acknowledgments

The Chuquicamata method of evaluating core-sludge assays was developed with the help of R. L. Hamilton, B. L. Renzetti, and B. A. Fahm of the Chuquicamata geological staff. Thanks are due these men for their help in working out the details of the system.

The writer wishes to thank C. M. Brinckerhoff, General Manager, Chile Exploration Co.; V. D. Perry, Chief Geologist, Anaconda Copper Mining Co.; and other officials of both companies for permission to publish this article.

The writer was unable to study all the literature on the subject of core-sludge evaluation because of his residence in a foreign land with limited library facilities. Sincere apologies are extended to those to whom proper credit may not have been given because of this situation.

References

[1] C. W. Greenhalgh: Calculations from Diamond-drill Sampling — a Comparison of Methods. MINING TECHNOLOGY (1946) 10, TP 1784.

[2] John J. Collins: Some Problems Involved in the Interpretation of Diamond-drill-hole Sampling and Surveying. MINING TECHNOLOGY (1946) 10, TP 1842.

[3] R. S. Moehlman: Diamond Drilling in Exploration and Development. MINING TECHNOLOGY (1946), 10, TP 1858.

[4] D. M. Davidson: Diamond-drill Sludge Sampling and Appraisal of a Weathered Ilmenite Ore Body, Piney River, Virginia. MINING TECHNOLOGY (1946) 10, TP 1951.

[5] V. D. Perry: Geology of the Chuquicamata Orebody. MINING ENGINEERING (1952) 4, p. 1166.

Mining Hydrology Problems in the Birmingham Red Iron Ore District

by Thomas A. Simpson

THE Birmingham red iron ore district in Jefferson County, north central Alabama, Fig. 1, is bounded on the northwest by the Warrior and Plateau coal fields and on the southeast by the Cahaba and Coosa coal fields. The area of study includes the ridge and valley between Red Mountain and Shades Mountain, Fig. 2, approximately 70 square miles extending from Homewood in the northeast to Greenwood in the southwest.

The district is one of the most important producers of hematite in the United States, with an annual production of about 7 million tons.[1] The amount of hematite mined between 1870 and 1950 ranged from 6 to 16 pct of the nation's total annual production,[2] and the iron and steel products from blast furnaces in the Birmingham district supply the entire southeastern section of the country.

Most of the mining in the Birmingham district is from slope mines along the outcrop of the ore on Red Mountain, such as Red Ore, Muscoda, Spaulding, and Sloss. The Pyne and the Shannon are the shaft mines of the area. The Shannon mine of Republic Steel Corp., in the central part of the area under study, is in Shades Valley at the foot of Shades Mountain. The Pyne mine of Woodward Iron Co. is 2 miles east of Readers Gap in Shades Valley.

The hydrology problem has become more prevalent as mining in the area has progressed downdip. An extensive exploratory diamond drilling program is necessary to determine areas where water pressures and abnormal flows are excessive. This operation, added to higher pumpage rates, has greatly increased the costs of ore extraction.

In November 1952 the U. S. Geological Survey began a detailed study of occurrence and movement of ground water in the iron mining areas of the Birmingham district. The study is a part of a small-scale but nationwide program to develop data that will be of help to the mining industry in solving mine water problems.

The area of the study, in the Ridge and Valley province of the Appalachian system, Fig. 1, is a series of alternate ridges and valleys trending northeast. The principal ridges are Red Mountain, altitude about 1000 ft, and Shades Mountain, about 1100 ft. Shades Valley is between these two ridges, and its lowest point is about 480 ft. Shades Moun-

T. A. SIMPSON is a Geologist, Ground Water Branch, U.S. Geological Survey, University, Ala.

Discussion on this paper, TP 39561, may be sent (2 copies) to AIME before March 31, 1955. Manuscript, June 14, 1954. New York Meeting, February 1954.

Publication of this paper is authorized by the Director, U.S. Geological Survey.

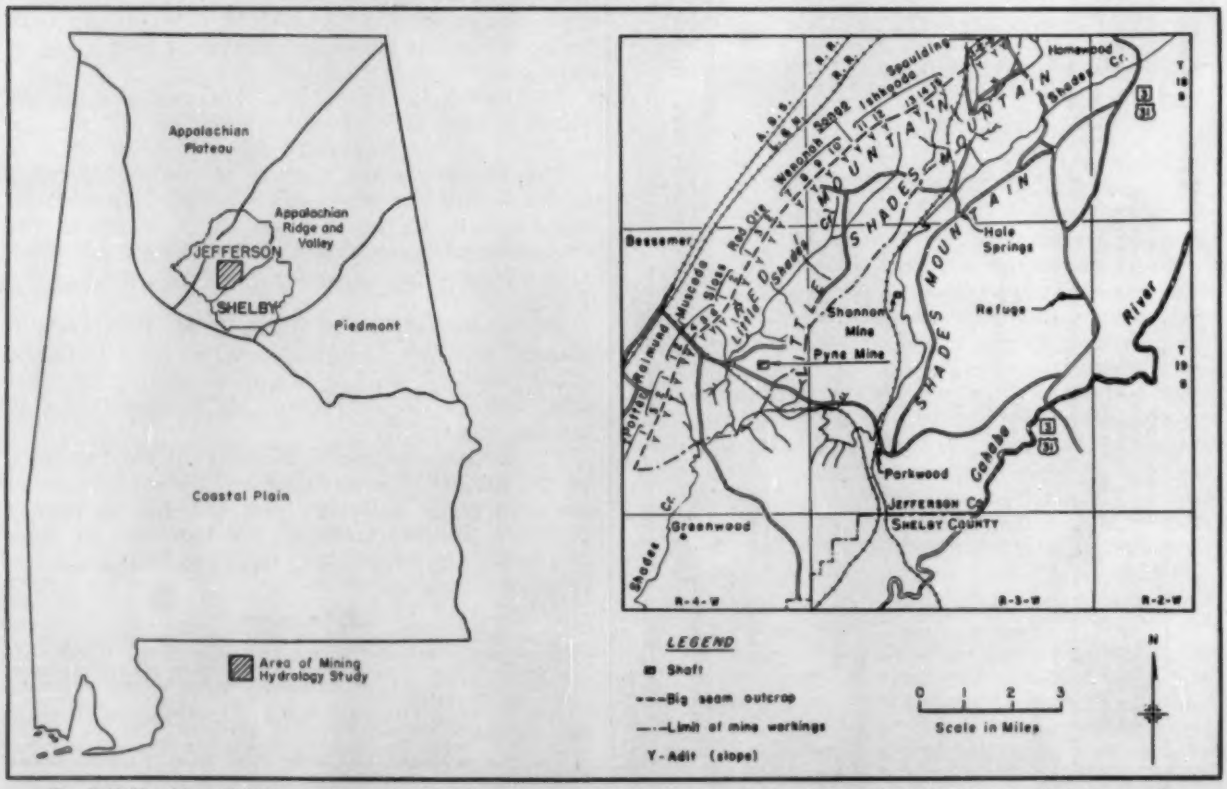


Fig. 1 (left)—Map of Alabama shows physiographical provinces and area of study. Fig. 2 (right)—Area of mining-hydrology study.

Table I. Geologic and Hydrologic Description of Paleozoic Rock Formations in the Birmingham District[5-7]

System	Formation	Thickness, Ft	Lithology	Water-Bearing Properties
Pennsylvanian	Pottsville formation	2600 to 7000	Conglomerates, shales, and sandstones, dark gray to brownish, thick-bedded; coal seams.	Poor aquifer; wells of reportedly low yields.
Mississippian (Carboniferous)	Parkwood formation	2 to 2000	Shale, massive, interbedded with hard sandstone layers.	Many domestic wells developed in sandstone and shales.
	Pennington shale	30 to 300	Shale interbedded with chert and pink shaly sands. Grades into Floyd shale to southwest.	Many domestic wells of low yield; water highly mineralized.
	Floyd shale	To 1000	Shale, dark bluish-gray, soft, fissile, with layers of silty sandstone.	Many domestic wells of low yield; water highly mineralized.
	Bangor limestone	100 to 300	Limestone, bluish, coarsely crystalline, thick-bedded.	Linked with two underlying formations to form one of best aquifers in area.
	Hartselle sandstone	75 to 100	Sandstone, brown to white, fine to medium-grained, quartzose, locally friable.	Locally one of the best aquifers in area
	Gasper formation	100	Shales, gray to bluish, with thin sandstone beds.	Good aquifer locally, but grades into massive shales to southeast.
	Warsaw limestone	100	Limestone, bluish-gray, coarsely crystalline, fossiliferous, cavernous.	Good aquifer in weathered zone. Well-developed joint pattern.
	Fort Payne chert	100	Chert, massive, iron and manganese stained bands, cavernous.	Good aquifer; lime weathers readily in weathered zone.
Devonian	Chattanooga shale	0 to 2	Shale, black to purple colored, dense, fissile.	Impervious. Probably absent from area.
	Frog Mountain sandstone	0 to 22	Sandstone, yellow to reddish-brown, fine to medium-grained, ferruginous, well-cemented.	Too thin to be an important aquifer.
Silurian	Red Mountain formation	200 to 300	Shales, limestones, sandstones; character varies from place to place; contains four iron ore seams of commercial importance.	Poor aquifer, occasionally furnishes good water supplies if not contaminated.
Ordovician	Chickamauga limestone	250	Limestone, grayish-colored, fine-grained, fossiliferous.	Too thin to be of importance as water producer.
Cambrian and Ordovician	Copper Ridge dolomite	2000	Dolomite, fine-grained, nodules of brittle compact chert.	Good aquifer; several wells yielding 150 gpm reported developed in dolomite.
	Ketona dolomite	400 to 600	Dolomite, dove to flesh-colored, medium-grained, massive.	Good aquifer. Wells yielding as much as 300 gpm reported from this formation.
Cambrian	Conasauga limestone	1900	Limestone, dark blue-gray, massive, locally thin-bedded and shaly.	Good aquifer. Wells yielding as much as 300 gpm reported from this formation.

tain, a sandstone ridge in the central portion of the area, bends sharply to the south, increasing the width of the valley from 2 miles in the northeast to 4 miles in the southwest.

The tilted formations of varying thickness and hardness were eroded by streams which formed a trellis-type drainage pattern. Most of the streams in the area dry up during periods of low rainfall. Some mine pumpage is emptied into streams, which flow continually throughout the year.

The rocks exposed in the area are consolidated Paleozoic sedimentary, ranging in age from Cambrian to Pennsylvanian, see Table I.[5-7]

The water-bearing properties of the formations overlying the Red Mountain formation have been discussed in part by W. R. Crane.[4] A study of Table I shows a thickness of about 600 ft of water-bearing material over the ore bed. In many instances water has entered the mine workings along fractures and breaks between the Red Mountain formation and Fort Payne chert.

Shades Valley is on the southeastern flank of an eroded assymetrical anticline that plunges southwest. The formations in general strike northeast and dip southeast, Fig. 3. The major folding, accompanied by much tearing and shearing of the formations, caused some low-angle thrust faults and minor fractures. They are mainly normal strike faults with a few tear faults, and the displacement of the faults ranges from a few to several hundred feet. The Shannon fault strikes to the northeast, and the vertical displacement increases from about 150 ft in Pyne mine to 300 ft in Shannon mine. The Dickey Springs fault was formed by the shearing of an anticline at the crest. Fort Payne chert and Warsaw limestone were brought to the surface at the fault approximately two miles from their outcrop on Red Mountain. Vertical displacement along the crest is about 200 ft.

Subsidiary drag folds on the limbs and flanks of the major structures are common throughout the area. The competency of the formations differs so greatly that structural irregularities are frequent and widely encountered in mining.

The limestones, sandstones, and shales overlying the ore beds have readily distinguishable joint patterns, although the joint system in one formation may be carried locally into the overlying forma-

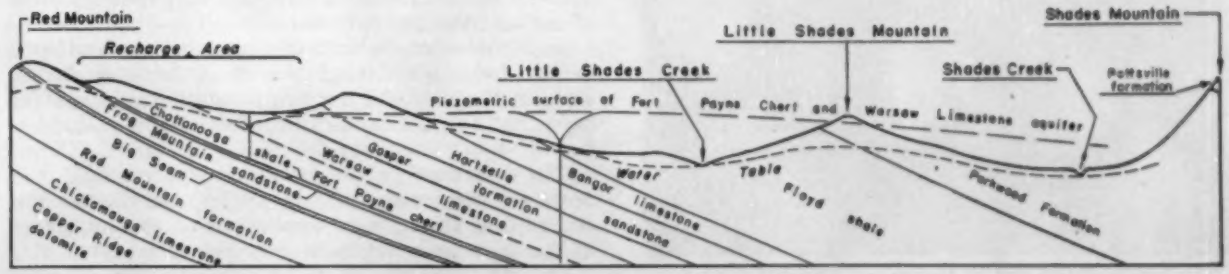


Fig. 3—Generalized diagrammatic section showing water table and artesian conditions in the Birmingham red iron ore district.

tions. One major set is at nearly right angles, the other nearly parallel to the strike. All joints have an almost vertical dip. Other sets are at various angles, depending upon the stress at time of folding. The chert apparently does not have a pronounced joint system, although it is extremely brittle. Slippage along the joint planes in the formations has been noted throughout most of the area. The joint sets contiguous to faults of high displacement have opened and become channels for the movement of ground water. Such is the case at Pyne mine where water pressures on the hanging wall side of the Shannon fault have been as high as 460 psi.

History of Mining-Hydrology Problem

The first record of large amounts of ground water in red ore mines was in 1909 at the Sloss No. 1. Mining operations weakened the roof support, and failure of the top rock brought in a flow of water that completely inundated the mine. The next year the mine was pumped out and mining operations were resumed. In 1932 a rock fall in Sloss No. 1 ore mine brought in a flow of water estimated at 4500 gpm. The flow remained constant for nearly a year but eventually leveled off to about 700 gpm.

In the process of sinking the Shannon shaft at 50° NW to the Big Seam in 1920 a large fault zone was penetrated. Water was encountered in the fault zone but was pumped out easily, and sinking of the shaft continued at a good rate. The shaft was lined with concrete because of the relative instability of the faulted ground. Further development work brought the working faces of several haulage slopes within 200 ft of the fault zone, which was 4 to 8 ft wide. Coreholes drilled into the face brought flows of pyritic mud and pebbles accompanied by hydrogen sulphide gas. A pressure gage installed on one of the holes registered 950 psi, indicating a hydrostatic head that came to within 300 ft of land surface. Subsequent grouting sealed off the flow and the fault zone was crossed successfully. New flows were encountered unexpectedly about 300 ft beyond the fault, where pressures of as much as 950 psi and water flows of 600 gpm were recorded.[5]

Small flows of water were encountered at 30 and 80 ft below the collar during the sinking of the hoisting shaft at the Pyne mine in the early 1920's. The water, reported to be about 13 gpm, was handled by bailing methods and did no more than create a hindrance to the shaft-sinking crew. Work in the mine was abandoned because of economic factors, and the shaft filled with water.

The Pyne mine was reopened in 1941, and development proceeded after the shaft was pumped dry. Flows were not stopped in the shaft until 1945, when a series of several diamond drillholes were sunk around the periphery of the shaft and grout was pumped in.

Fig. 4—Equipment used to measure water level in corehole W-27 in Pyne mine area.

Diamond drillholes that penetrated the Shannon fault zone had pressures ranging from 125 to 500 psi. A new haulageway and air course were later driven through and about 1000 ft beyond the fault zone. Great amounts of water were not encountered in the driving operations, but water courses were grouted off through the diamond drillholes. Development proceeded to the northeast and southwest 1000 to 1300 ft beyond the fault zone.

A rock fall occurred in 1950 in the Muscoda mine of the Tennessee Coal, Iron, and Railroad Co. An initial estimated flow of 3000 gpm was said to have increased to nearly 4000 gpm a month later, but mining continued as the pumps handled the water.

In April 1952 two rock falls in the Songo mine of the Woodward Iron Co. released about 900 gpm, and rock falls and water flows increased throughout the remainder of the year. Efforts were made to increase the pumping capacity, but on September 16 a new fall resulted in about 2000 gpm, and it was obvious that the mine would become flooded even with the installation of new pumps.

The dewatering of the Songo mine begun in October 1952 promises to be successful. Additional pumps discharge an average of 4000 gpm 24 hr a day. The level of the water has fallen continuously, and dewatering is ahead of schedule.

In the spring of 1953 a rock fall in the Red Ore slope mine of the Woodward Iron Co. brought in a small amount of water, but the flow was not enough to hamper mining operations.

As increased depth is gained in mining down the dip, all the operators have tried grouting to impound flows of water. This has been successful where small fissures and seeps along the joint planes have afforded channels for movement of ground water. The grout is pumped under pressure into diamond drillholes, the pipe is plugged and sealed off, and when the cement sets it affords an effective seal against further circulation of ground water.

Where dangerous water conditions exist, diamond drillholes 250 ft ahead of the working face are used to disclose the existence of water courses. If water is found, grout is pumped through the hole in an effort to seal off the flow. If the flow is stopped, advance of the heading is started again; if the flow is not stopped, more holes are drilled and grout is again used. Should grouting fail entirely, attempts to advance the heading are halted and development work started at a different place in the mine. One hole took 120 bags of cement before the flow could be stopped.

Pumping facilities are well placed in most of the mines; some of the equipment is old but in good condition. Sumps and booster pump stations have been located strategically, and many of the pump stations have automatic switches that require little attention from the operators.

In Pyne mine, where the haulageway and aircourse have penetrated the fault zone, a strong watertight bulkhead has been installed with a steel door that can be swung into place should a sudden flow of water inundate the mine.

The attempts of the operators to impound the flows are only temporary measures, and to date the source and direction of movement of ground water in the area have not been fully determined.

The study by the U. S. Geological Survey begun in November 1952 is planned to collect data over a

Fig. 5—Automatic water-level recorder installation on well overlying mining area.

period of several years as an aid to understanding the occurrence and movement of ground water in the mines.

Surface geology and drainage will be plotted on a base map that has been constructed from aerial photographs. The geologic structure is most important as it controls the direction of flow of water in the ground-water basin or basins. As faulting is one of the most common structural features present in the area, a detailed study of the faulting and related structural features will be carried out.

A piezometric map of the area, although not complete, shows several possible ground-water basin areas following very closely the trends of the subsurface structure. It also shows direction of movement of ground water and extent to which overlying formations are saturated.

About 400 private and municipal wells and 20 coreholes have been studied and plotted on the base map, which is now being compiled for publication. The altitude of the water table during various seasons of the year can then be observed from the measurement of these wells, see Fig. 4, and the trend can thus be used to determine the magnitude of recharge to the ground-water reservoirs.

Instruments, Fig. 5, which give a continuous record of water levels in wells have been installed on several key wells. The hydrographs prepared from data collected show daily fluctuation in water levels caused by pumpage, dewatering, and evapotranspiration losses. A graph from an installation on the southeastern slope of Red Mountain shows rapid recharge occurring within one to two days after a rain, whereas the hydrographs from wells in the valley show a lapse of a week or more. The extent of weathering of the formations downdip has not been determined fully, but a study will be made to determine the extent of this factor. At the Sloss mine the operators drilled 4 vertical coreholes near the bottom of the mine workings up into the overlying formations. About 200 ft of solid chert and limestone were encountered in drilling the holes. Dependent upon the amount of cover and structure, there is a definite gradation of the weathered zone of the outcrops to a solid, dense formation. Previous investigators place the extent of this zone approximately 1000 ft downdip from the outcrop of the Big Seam.

Flow and pressure studies are planned to determine coefficients of storage and transmissibility of rock formations. Such information will be invaluable to the mine operators when pump capacities have to be computed for continued operations. Pumping tests will be run to obtain more data on the hydraulic properties of the materials in the ground-water basins. A definite problem of differential permeability is further aggravated by the many lithologic changes within the formations.

Field analyses have been made of water samples from more than a hundred wells and a few complete analyses of water samples from several of the mines. The field analyses include determination of pH, total hardness, dissolved iron, silica, chlorides, and color. As yet geochemical studies have not been used a great deal as a qualitative means of study, but they will be a useful tool to help determine the source of flow. Temperatures of the ground water have been taken in most of the wells and at a few points underground in the mines but give no significant clues as to the source of water.

Miscellaneous experimental techniques such as models and the development of grouts and chemical seals may be used eventually. Grouting so far seems to have been the immediate answer to enable development work to continue in the mines. A complete knowledge of the overlying geologic structure might be a guide for the use of grout. Faulting, folding, and jointing are the controlling factors of the flow of grout. However, the advisability of grouting seems questionable when the main flows of water and high pressures are still present. The grout may be *pooling* the water or impounding it to such an extent that higher pressures may appear eventually.

Large-scale development programs of mining operations are definitely hampered where a water problem exists. A thorough study of the existing water problem in mines further updip and under less cover, however, will be a benefit to the operators for future exploitation and development.

Field work during the present study has not developed enough complete evidence to warrant decisive conclusions. The most that can be expected of the study is a practicable working solution to the problem to enable the operators to continue development work with confidence and without their present risk. The least to be expected is an accurate and careful compilation of hydrologic data that will be available as a reference for future years.

Acknowledgments

Acknowledgment is made of the cooperation of members of the engineering staffs of the Woodward Iron Co. and the U. S. Pipe and Foundry Co. Appreciation is due A. C. Blair, consulting geologist, who discussed the geology of the area with the author. The project is under the direct supervision of P. E. LaMoreaux, district geologist of the Ground Water Branch of the Geological Survey in Alabama, and W. T. Stuart, engineer in charge of mining-hydrology projects of the Geological Survey. Both have contributed their time and their ideas to make this paper possible.

References

[1] J. R. Thoenen, A. H. Reed, Jr., and B. H. Clemmons: The Future of Birmingham Red Iron Ore, Jefferson County, Ala. U. S. Bur. Mines *R.I. 4988* (July 1953) p. 1.

[2] Ref. 1, p. 4.

[3] W. H. Robinson, J. B. Ivey, and G. A. Billingsley: Water Supply of the Birmingham Area, Ala. USGS Circ. 254 (1953) p. 51.

[4] W. R. Crane: Drainage in the Red Iron Ore Mines of the Birmingham District, Alabama. AIME TP 1639L. Consolidated with TP 1475A by the same author and published as Subsidence and Its Relation to Drainage in the Red Iron Mines of the Birmingham District, Alabama, *Trans.* AIME (1927) 75, pp. 837-869.

[5] J. S. Crawhall: Cement Grouting Solves Serious Mine Water Problem. *Engineering and Mining Journal* (April 27, 1929) pp. 675-679.

[6] E. F. Burchard and Charles Butts: Iron Ores, Fuels, and Fluxes of the Birmingham District, Ala. USGS *Bull. 400* (1910) p. 13.

[7] G. I. Adams, Charles Butts, L. W. Stephenson, and Wythe Cooke: Geology of Alabama. Alabama Geol. Survey *Spec. Rept.* 14 (1926) pp. 139-141.

Quartz Flotation with Anionic Collectors

by A. M. Gaudin and D. W. Fuerstenau

IN concentration of certain ores by soap flotation, prevention of quartz flotation is desired; the contrary is true in treatment of some oxide iron ores. Experimental study of the flotation of quartz goes back at least a quarter of a century.[1] Clean quartz does not float with fatty acids or soaps but does float when activated by one of many metallic salts. Control of pH is important.

Broadly speaking the problem of quartz flotation has been approached from the empirical side, as was the related topic of flocculation or dispersion of quartz suspensions.[2] Empirical studies indicated the existence of critical relationships between the additions of collector and activator. These additions were not stoichiometric for the formation of soaps of the activator cation. For example, Gaudin and Rizo-Patrón[3] found optimum quartz flotation at pH 10.6 using barium activation and oleate collection when the molar ratio of oleate to barium was 1 to 1 instead of 2 to 1, as would be called for formation of $Ba(OL)_2$. Cooke and Digré[4, 5] found that if calcium is the activator, a minimum quantity of that agent is required for effective flotation when the pH is 11.5. In other words, if the concentration of Na^+ exceeds $10^{-2.5}$ mols per liter or if the concentration of H^+ exceeds $10^{-11.5}$ mols per liter, the concentration of Ca^{++} in solution required for quartz activation is increased. This suggests that H^+ is much more effective than Na^+ on quartz, perhaps in the ratio of $\frac{10^{-2.5}}{10^{-11.5}}$ or 10^9. Schuhmann and Prakash[6] studied anew the activation of quartz by barium, calcium, aluminum,[7] and ferric iron. Salts of these metals are activators provided they are in stoichiometric excess over the collector used with them. Alkaline-earth salts are effective only in alkaline circuits.

Important as they are in giving data on the effect of various agents on quartz, all these studies fail to give information on the detailed structure of the quartz-solution interface. A beginning in this direction was made by Gaudin and Chang,[7] who measured the adsorption of radioactively marked barium and laurate ions at quartz surfaces, and by Gaudin, Spedden, and Laxen,[8] who measured the adsorption of radioactively marked sodium at quartz surfaces. Work has also been done by Bell[9] on measurement of the adsorption of sodium ion and chloride ion at quartz-solution interfaces.

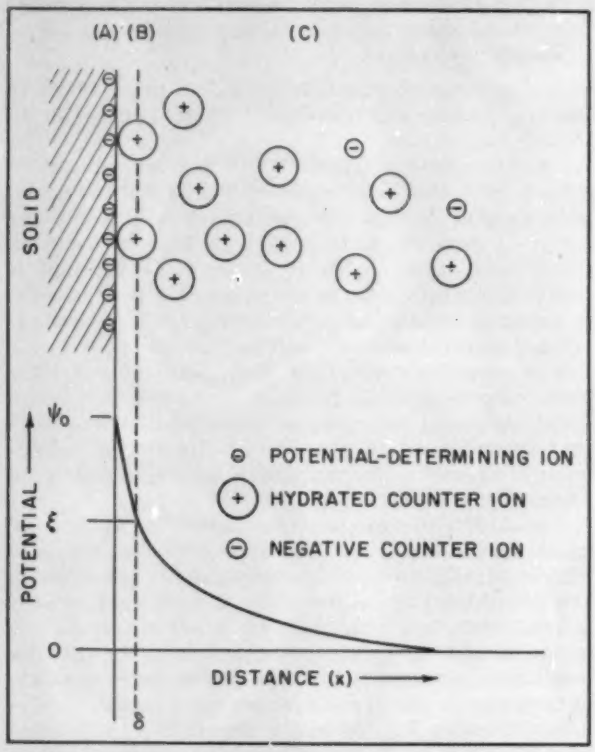


Fig. 1—Schematic representation of the structure of the double layer and potential distribution in the double layer in electrolyte solutions. *A*, potential determining ions; *B*, fixed layer of counter ions in the Stern plane; and *C*, diffuse layer of counter ions (Gouy layer).

In all these experimental measurements of adsorption, the solid was centrifuged or filtered from the bulk of the liquor with which it had been associated; and the composition of the solid surface was ascertained by analysis, after allowance was made for the ionic composition of the liquor included with the centrifuged solids on the assumption that it is identical to the bulk liquid. Adsorption measurements give only the total amount of collector adsorbed at the quartz-solution interface; they give no indication of the distribution of these adsorbed ions at the interfacial layer. It is the ionic structure of the solid-solution interface and its importance to flotation that is the subject of this paper. The structure of this interfacial layer can be investigated by means of electrokinetic methods so that by combining electrokinetic studies with adsorption measurements, a more complete picture of the quartz surface may be obtained. The following studies were made to ascertain how electrolytes used in the soap flotation

A. M. GAUDIN and D. W. FUERSTENAU, Members AIME, are, respectively, Richards Professor of Mineral Engineering and Assistant Professor of Mineral Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Discussion on this paper, TP 3964B, may be sent (2 copies) to AIME before March 31, 1955. Manuscript, Aug. 9, 1954. Chicago Meeting, February 1955. Condensed from a thesis submitted by D. W. Fuerstenau in partial fulfillment of the requirements for the degree of Doctor of Science at Massachusetts Institute of Technology.

of quartz affect the electrokinetic potential at the quartz-solution interface.

Quartz is negatively charged in water and in most dilute aqueous suspensions.[10-12] This phenomenon is explained by the unsymmetrical distribution of anions and cations at an interface with the formation of a double layer of ions. In this particular system, the anions predominate at the solid surface and the cations form the other part of the double layer in the adjacent solution.

There are several methods of evaluating the electrokinetic potential.[13] Each has its advantages and area of applicability. Gaudin and Sun,[11] for instance, used the method of electrophoresis. The present writers have preferred the method of streaming potentials because the experimental data involved in the computation of the electrokinetic potential can be measured with greater accuracy and facility than when the other methods are used. The method is well known to physical chemists, and details of the technique are given in the thesis by Fuerstenau.[14]

The Electrical Double Layer

The modern concept of the electrical double layer, an outgrowth of the work of Helmholtz, Perrin, Chapman, Gouy, and Stern, is clearly set forth in the text of Kruyt.[13] As may be seen from the schematic Fig. 1, the electrical double layer according to Stern consists of three parts arranged as follows from the solid to the liquid: 1—the potential-determining ions which may be regarded as part of the solid lattice, 2—the counter ions held directly to the surface in a plane called the Stern plane, which is but a few Angstrom units in thickness, 3—the counter ions which form an atmosphere called the diffuse or Gouy layer. In this layer, the ion population density decreases exponentially with distance from the surface. The center of gravity of this space charge, which is given by the Debye-Hückel theory, may be called the *thickness* of the diffuse layer. The thickness of the Gouy layer is inversely proportional to the square root of the ionic strength and is about 1000 Å thick in 10^{-4} molar solutions.

The potential-determining ions may be regarded as the prime reason for the existence of the electrical double layer, the counter ions being drawn by electrostatic forces to maintain electroneutrality at the interfacial layer. The Stern layer ions are believed held to the surface, whereas the ions in the Gouy layer move about freely.

When the solution moves relative to the solid, shear takes place at a plane probably within one or two molecular dimensions from the interface. This plane may be assumed to coincide with the boundary between the Gouy and Stern layers, δ, although there is no way of proving this experimentally. On this assumption, the ions in the Gouy layer are carried with the liquid. The electrical potential at the slipping plane (with respect to a point far out in the bulk liquid) is called the zeta potential ζ.

The total potential across the double layer, commonly referred to as the surface potential, ψ_0, is determined by the concentration of potential-determining ions in solution only.[13] At present it is not susceptible to measurement in the case of quartz. The zeta potential is smaller in absolute value and depends not only on ψ_0 but also on the total electrolyte concentration, the location of the slipping plane, and the charge distribution.

The method depends on the interrelation of mechanical and electrical phenomena at solid-solution interfaces. Streaming potentials are determined by measuring the potential difference between the ends of a porous plug of particles when the liquid is forced through the plug. The zeta potential is given from streaming potential data by Eq. 1:[13]

$$\zeta = \frac{4\pi\eta}{\epsilon} \cdot \frac{\lambda E}{P} \qquad [1]$$

in which η is the viscosity, ϵ the dielectric constant, λ the specific conductance, E the streaming potential, and P the applied pressure difference. In aqueous systems at 25°C the equation becomes

$$\zeta = 9.69 \times 10^4 \frac{E\lambda}{P} \text{ mv} \qquad [2]$$

with E, P and λ being respectively, the streaming potential in millivolts, the driving pressure in centimeters of mercury, and the specific conductance of the solution within the plug in ohms^{-1} cm^{-1}.

The following conditions must be satisfied if this equation is to be valid:

1—The flow of liquid through the plug must be laminar if E/P is to be constant. Experimentally it was found that the streaming potential, E, is directly proportional to the pressure, P, up to at least 46 cm of mercury and that it is independent of the direction of flow of the liquid.[14]

2—The size of the pores must be many times larger than the thickness of the double layer. Bull showed that the measured value of the zeta potential of quartz in 2×10^{-4} molar sodium chloride solutions decreases rapidly as the particle size is reduced below 163 microns.[15] This critical size increases for more dilute solutions. For this investigation 48/65-mesh quartz was chosen.

3—Surface conductance should not be of importance in determining the conduction current through the plug and streaming potentials measured in a porous plug often yield erroneous results in dilute solutions.[13] It will be shown later that data obtained in solutions of less than 10^{-4} normality may be low.

To calculate the zeta potential, it is necessary to measure experimentally the driving pressure, streaming potential, and specific conductance.

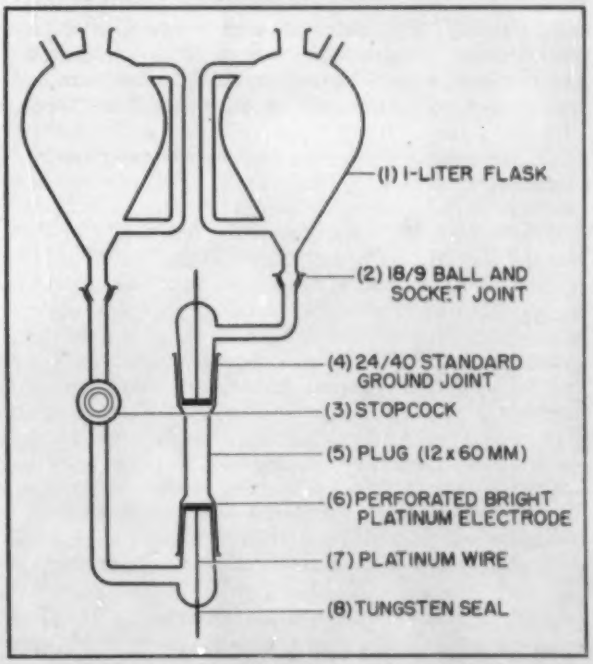

(1) 1-LITER FLASK
(2) 18/9 BALL AND SOCKET JOINT
(4) 24/40 STANDARD GROUND JOINT
(3) STOPCOCK
(5) PLUG (12 x 60 MM)
(6) PERFORATED BRIGHT PLATINUM ELECTRODE
(7) PLATINUM WIRE
(8) TUNGSTEN SEAL

Fig. 2—Diagram of the streaming potential cell.

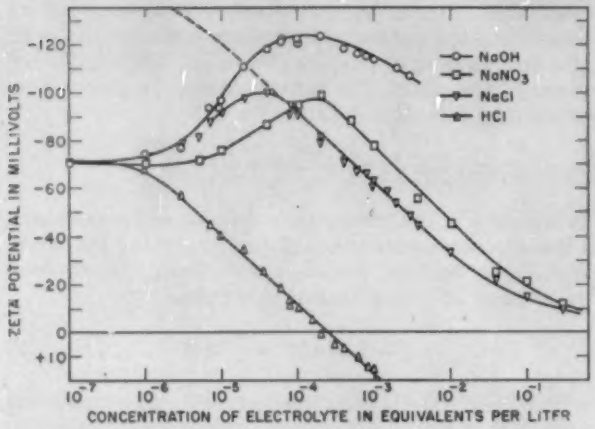


Fig. 3—Zeta potential of quartz in solutions of four different electrolytes.

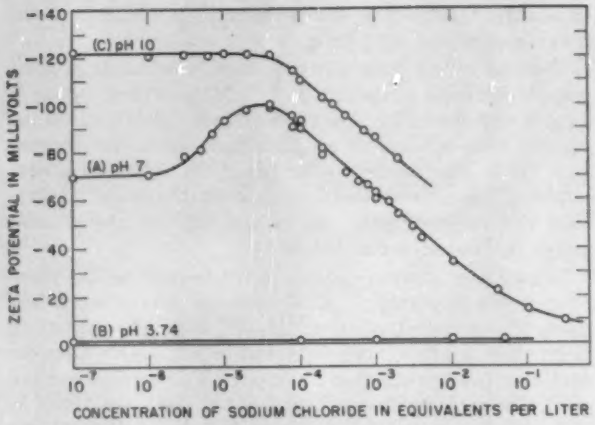


Fig. 4—Zeta potential of quartz in solutions of sodium chloride at different pH values.

The apparatus for measuring zeta potentials consists of the cell assembly, Fig. 2, a source of purified nitrogen for driving solution through the plug of mineral particles, manometers, and an electrical circuit for measuring E and λ. For E, the electrical circuit consists of a potentiometer with a vibrating reed electrometer as a null point instrument. For resistances less than 1 megohm, the specific conductance is determined with a Wheatstone bridge utilizing 1000-cycle ac, while for resistances greater than 1 megohm, a dc bridge is used, patterned after Gortner.[37] To measure the specific conductance of solutions with the dc bridge, the flow of solution must be stopped. However, measurements with the ac bridge can be made with the solution either flowing or stopped. The accuracy of zeta potentials calculated from data obtained with this apparatus is about 0.5 pct.

The quartz used in this research was the 48/65-mesh fraction obtained from crushing selected quartz crystals. The crushed product was leached repeatedly in boiling concentrated hydrochloric acid until no discoloration of the acid by dissolved iron was observed. The quartz was washed with distilled water until the filtrate showed no trace of chloride ion. Finally the material was washed with and stored under conductivity water. This water had a specific conductance less than 7×10^{-7} ohm^{-1} cm^{-1}. It was stored and dispensed in an atmosphere free of carbon dioxide. All inorganic chemicals were of reagent grade. Sodium laurate was made from a stock of high purity lauric acid.[38]

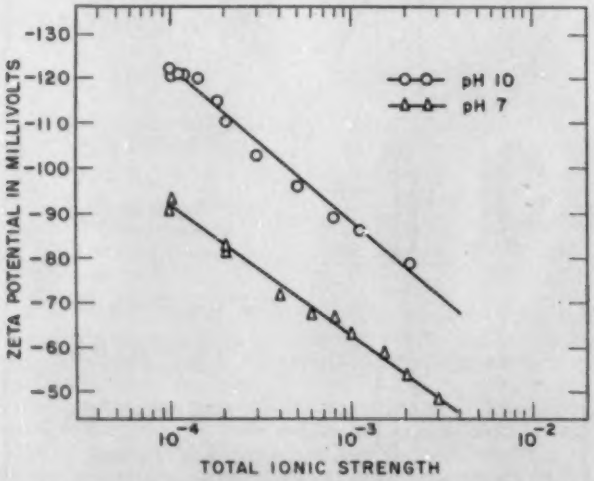


Fig. 5—Effect of total ionic strength on the zeta potential of quartz in solutions of 1-1 valent simple electrolytes.

Quartz in Conductivity Water: In this investigation quartz particles in conductivity water were found to have a zeta potential of —70 mv. From electrophoresis experiments, the zeta potential of quartz in water was reported to be —44 mv by Blake and Whitney,[39] —50 mv by Freundlich,[10] and —36 mv by Gaudin and Sun.[11] The experimental procedure for studying electrophoretic phenomena is difficult and interpretation of the data is uncertain. Hence, calculation of the zeta potential from electrophoretic data may not be reliable. Using the streaming potential method with a vitreous silica capillary, in 1946 Wood reported the zeta potential of vitreous silica in water to be —177 mv.[39]

The low values of ζ found with quartz particles in water points to a defect in the experimental method. Using the streaming potential method, Overbeek and Wijga found that ζ evaluated from plugs of powdered glass is —70 mv against —140 mv for a capillary of the same glass in conductivity water, whereas the two values are —98 mv and —112 mv, respectively, for 2×10^{-4} molar potassium chloride.[38] This apparent lowering of ζ in experiments conducted with particles in dilute solutions has been attributed to the effect of so-called *surface conductance* in the plug.[34, 35] Surface conductance results from the double layer contributing substantially to the total conductance in the plug. Corrections for surface conductance cannot be made for porous plugs because the pore size between particles varies widely.

Monovalent Electrolytes: From experiments with solutions of various electrolytes, straight lines are generally found if ζ is plotted against the logarithm of the electrolyte concentration.

Fig. 3 shows that in aqueous sodium chloride and sodium nitrate solutions ζ increases in absolute value with electrolyte concentration up to about 10^{-4} molar where ζ is about —100 mv; for higher concentrations ζ decreases in proportion to the increase in the logarithm of the concentration until 0.01 molar solutions are reached. At still higher concentrations, ζ approaches zero as a limit, but does not change sign. The hump in the curves, which is obtained with 1-1 valent electrolytes, results from surface conductance in the plug,[35,38] and the ζ —log C curve for sodium chloride with correction for surface conductance should perhaps have the appearance of the dotted line in Fig. 3, with the true value of ζ in water be-

ing about —150 mv. Only for experiments with solutions of total ionic strength greater than 10^{-4} is the value of ζ correct.

In solutions of sodium hydroxide, the zeta potential of quartz increases in absolute value with concentration to reach a maximum of —125 mv at about 10^{-4} molar; for higher concentrations the potential decreases somewhat. Since there is no reason to expect surface conductance to play a more prominent role in sodium hydroxide solutions than in solutions of other sodium salts, this observation points to a special function of hydroxyl ions in the system as compared to chloride and nitrate ions.

As the concentration of hydrochloric acid in water is increased, the zeta potential of quartz changes continuously from negative to positive values. At a hydrogen ion concentration of 1.9×10^{-4} *N* (pH 3.7) the value of ζ is 0. The marked difference between hydrochloric acid on the one hand and sodium chloride on the other suggests again that the role of hydrogen ions is different from that of sodium ions.

To prove further that hydroxyl ions and hydrogen ions behave differently at the quartz surface from simple monovalent chloride and sodium ions, the zeta potential was measured as a function of concentration of sodium chloride at pH 10, pH 7, and pH 3.74. The data are recorded in Fig. 4. Curve *A* illustrates the effect of aqueous sodium chloride solutions on ζ and shows that sodium ions do not change the sign of ζ. Curve *B* shows that at pH 3.74, sodium chloride additions do not change the sign or magnitude of ζ, which is only —1 mv and must therefore be determined mainly by the hydrogen ion concentration. Curve *C* points out that the zeta potential of quartz is not affected by the addition of sodium chloride to solutions at pH 10 until the total ionic strength of the solution is changed appreciably.

To illustrate this more clearly, the value of ζ is plotted as a function of the logarithm of the total ionic strength in Fig. 5. It can be seen that for a given ionic strength of 1-1 valent electrolyte, the value of ζ is determined by the pH of the solution, but it can be reduced by increasing the total ionic strength of the solution.

Plotting the zeta potential of quartz as a function of pH for different concentrations of sodium chloride, see Fig. 6, shows that the zero point of ζ is determined by the pH of the solution and is independent of the concentration of sodium and chloride ions. Thus hydrogen and hydroxyl ions must have a special function at the quartz surface as compared to sodium ions and chloride ions.

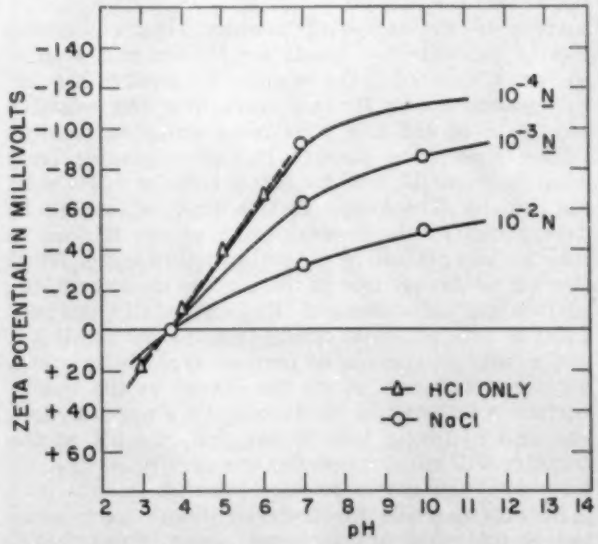


Fig. 6—Zeta potential of quartz as a function of pH for different concentrations of sodium chloride.

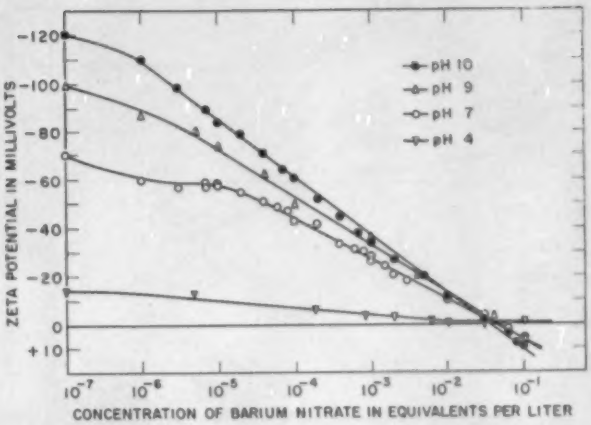


Fig. 7—Zeta potential of quartz in solutions of barium nitrate at different pH values.

Barium Nitrate: Fig. 7 illustrates the variation of ζ with concentration of barium nitrate at different pH values. At pH 10, pH 9, and pH 7, the zeta potential of quartz decreases in absolute value as a linear function of the concentration of barium nitrate and becomes positive at about 0.02 mols per liter. At pH 4, the value of ζ approaches 0 at high concentrations of barium nitrate but does not change sign. These experiments show that barium ions behave differently from sodium ions in that aqueous barium nitrate solutions can change the sign of ζ at high concentration, whereas aqueous sodium nitrate solutions do not. In addition, increasing the concentration of sodium chloride at pH 10 does not change the value of ζ until the ionic strength is changed, whereas at pH 10 even 10^{-6} equivalents Ba^{++} per liter reduce ζ. Even though barium ions change the sign of ζ, monovalent hydrogen ions change the sign of ζ at a concentration 100 times more dilute than is required for barium nitrate. This confirms the special role of hydrogen ions at the quartz surface, a role which is also distinct from that of barium ions which do not change the sign of zeta potential at pH 4.

Aluminum Nitrate: As can be seen from Fig. 8, in aqueous solutions of aluminum nitrate, ζ decreases abruptly at concentrations exceeding 1×10^{-6} equivalents per liter and becomes positive in solutions containing 2×10^{-6} equivalents per liter. Measurements of pH showed that hydrolysis is present in aluminum nitrate solutions; possibly the quartz surface is covered with a layer of colloidal aluminum hydroxide. A series of experiments run at pH 4 to prevent hydrolysis shows that aluminum ions change ζ continuously from negative to positive values; ζ changes sign in solutions containing 2×10^{-5} equivalents Al^{+++} per liter at pH 4. The affinity of metallic cations for the surface follows the order: $Al^{+++} > Ba^{++} > Na^{+}$.

Sodium Laurate and Sodium Oleate: Gaudin and Chang observed that some laurate ions are adsorbed in the absence of an activator.[7] Since quartz does not float under these conditions, laurate ions are probably not attached to the quartz surface. To determine how laurate ions are distributed between the quartz-solution interface and the bulk of the

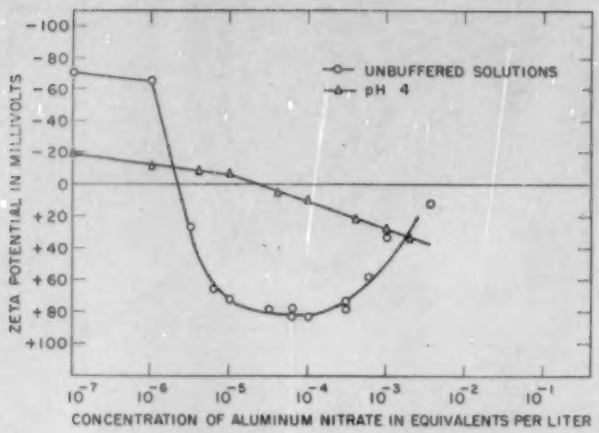


Fig. 8—Zeta potential of quartz in solutions of aluminum nitrate.

solution, ζ was measured in solutions of sodium laurate and sodium oleate at pH 10. The experimental results are presented in Fig. 9, Curve *A*, which is a plot of ζ as a function of the logarithm of the concentration of sodium chloride, sodium laurate, and sodium oleate. The data indicate that these three salts function in the same manner as simple 1-1 valent electrolytes because ζ is unaffected until the total ionic strength of the solution is increased above 10^{-4}. Since the zeta potential of quartz does not become more negative under these conditions, it can be concluded that laurate or oleate ions do not lie next to the quartz surface. Because of the negative charge at the quartz surface, the counter ions must be cations; accordingly, the concentration of chloride, laurate, or oleate ions in the diffuse layer would be smaller than in the bulk solution.

Gaudin and Chang[9] found that the presence of laurate ions does not affect the adsorption of barium ions. The amount of barium ions adsorbed at the quartz surface is controlled by pH and the concentration of barium ions alone, but the adsorption of laurate ions is markedly affected by the presence of barium ions. The zeta potential of quartz at pH 10 and pH 11.2 in solutions of 10^{-4} *N* barium nitrate at different concentrations of sodium laurate is given in Fig. 9, curves *B* and *C*. The maximum laurate-ion concentration was limited because precipitation of barium laurate occurred when the concentration of sodium laurate exceeded 3×10^{-4} *N* and 4×10^{-4} *N* at pH 10 and pH 11.2, respectively. These experimental results show that ζ is dependent only on the pH and barium-ion concentration until the total ionic strength of the solution is changed. (Compare with NaCl data in curve *B*.) The maximum permissible concentration of sodium laurate was not sufficient to change the ionic strength appreciably and ζ remained unchanged by sodium laurate additions. Since barium ions and hydroxyl ions have been shown to control the surface conditions of quartz even in the presence of laurate ions, it appears that the mechanism by which laurate ions are attached to quartz is through the electrostatic attraction brought about by cations in the Stern plane.

Discussion of Results

Potential-Determining Ions: Results of the foregoing streaming potential experiments indicate that hydroxyl and hydrogen ions are potential-determining ions for quartz. Potential-determining ions are ions responsible for the existence of the double layer and determine the electrical potential difference between the solid and liquid phase. They are the ions common to both phases for ionic crystals or are the ions which participate in the electrolytic reaction that establishes equilibrium at the interface. For example, the potential-determining ions for silver iodide are silver and iodide ions, whereas for the glass electrode hydrogen and hydroxyl ions function as potential-determining ions.[12]

The following experimental results indicate that hydrogen and hydroxyl ions are potential-determining for quartz: 1—Hydroxyl ions cause ζ to become more negative than any other anion tested. 2—Hydrogen ions change the sign of ζ in solutions at pH 3.7, whereas sodium ions reduce ζ to zero at extremely large concentrations. 3—The zero point of zeta potential is determined by pH regardless of the concentration of a 1-1 valent electrolyte such as sodium chloride. 4—In solutions of electrolytes at a given total ionic strength (same thickness of the double layer), the value of ζ at the quartz-solution interface is determined by pH.

The adsorption of hydrogen and hydroxyl ions give rise to the electrical double layer at the quartz

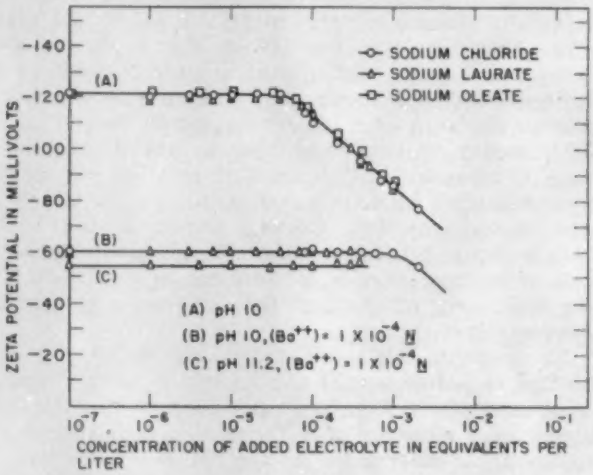


Fig. 9—Zeta potential of quartz at pH 10 upon addition of sodium chloride, sodium laurate, and sodium oleate; zeta potential of barium-activated quartz at pH 10 and pH 11.2 upon addition of sodium laurate and sodium chloride.

surface in the following manner. Upon crushing quartz, —Si—O—Si— bonds are broken and a polar surface is created in the manner depicted in Fig. 10. In aqueous media H^+ ions react with the negative oxygen sites and OH^- ions react with the positive silicon sites. The surface charge originates from dissociation of H^+ ions from this *surface silicic acid*, see Fig. 10. The extent of this dissociation will be determined by the concentration of the H^+ ions in solution and pH will be potential-determining. When there is no dissociation of the surface silicic acid, the surface will be uncharged. Experimentally, the zero point of zeta potential occurs in solutions at pH 3.7, and at this pH there is no double layer about quartz particles in water. Since the charge at the quartz surface is determined by the concentration of hydrogen and hydroxyl ions in solution, the pH of the solution will affect markedly the adsorption of electrolytes at the quartz-solution interface.

Surface-Inactive Electrolytes: Some electrolytes reduce the value of ζ by compression of the double layer without changing its sign. They are generally called surface-inactive electrolytes or indifferent

electrolytes. Sodium chloride and sodium nitrate are of this type in regard to quartz, the sodium ions functioning as counter ions.

Surface-Active Indifferent Electrolytes: If the counter ions are specifically attracted to the surface by chemical forces in addition to electrostatic forces, they may reverse the sign of ζ, as is the case with barium or aluminum ions.

In neutral or alkaline solutions, barium ions are specifically adsorbed by quartz because ζ can be reversed in solutions containing about 0.02 mols barium nitrate per liter. However, this specific affinity of barium ions for the surface does not appear to exist at pH 4. Yet aluminum ions still show specific adsorption at pH 4. These findings agree with flocculation studies and with flotation studies on quartz.[2,5,6]

When ζ is reversed by specific adsorption of counter ions such as Ba^{++}, a triple layer is formed at the quartz solution interface: 1—the adsorbed layer of potential-determining ions, 2—the layer of specifically adsorbed Ba^{++} ions in the Stern layer, and 3—the diffuse layer of nitrate counter ions.

Soap Flotation of Quartz: It has been shown that when crushed quartz particles are put into water, the surface becomes negatively charged by the reaction of exposed polar sites with H^+ and OH^- ions followed by ionization of H^+ ions from the *surface silicic acid*. If the pH of the solution is increased, the dissociation of H^+ ions from the surface increases with the surface becoming more negatively charged, and therefore a greater number of cations must be attracted to the surface to maintain electroneutrality. If sodium hydroxide is used to regulate pH, the counter ions are sodium ions. However, upon addition of Ca^{++} or Ba^{++} ions as activator, these divalent ions replace the sodium ions because of the valency effect.[10] Now what happens when sodium oleate or sodium laurate is added to the system?

Fig. 9A shows that in the absence of an activator sodium laurate functions as surface-inactive electrolyte with Na^+ ions being the counter ions at the quartz-solution interface, and any laurate ions in the double layer probably occur in the outer extremities

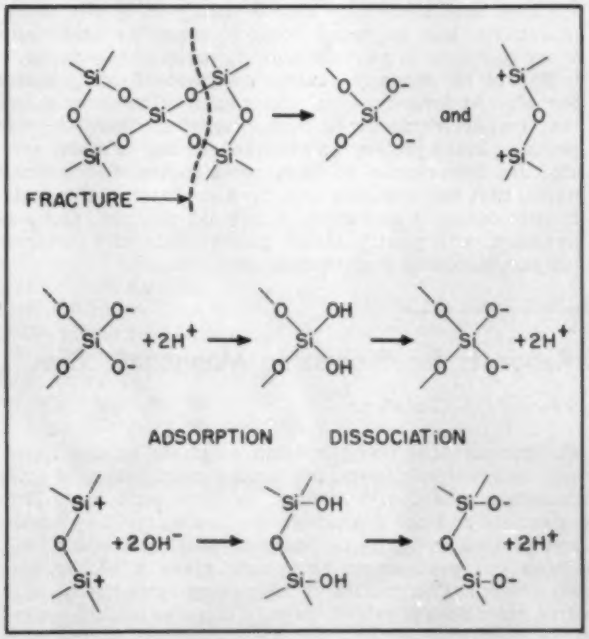


Fig. 10—Mechanism for the origin of the electrical charge at the quartz surface in aqueous solutions.

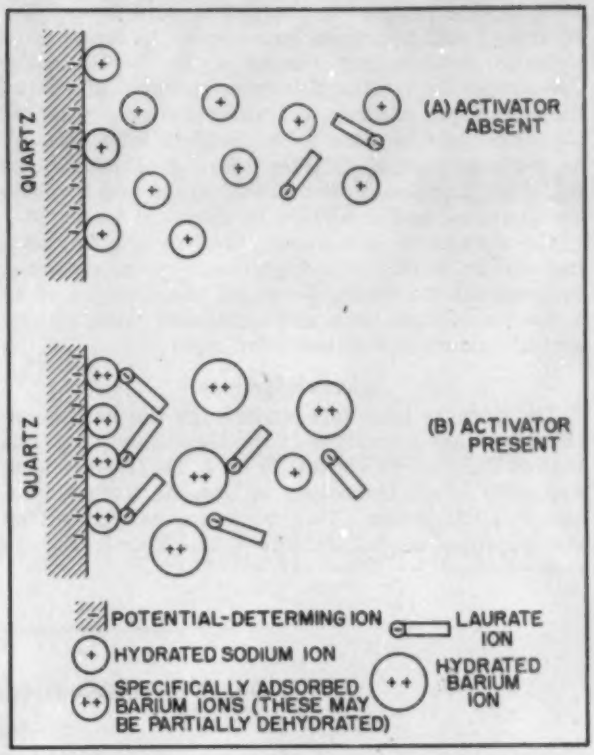


Fig. 11—Distribution of laurate ions at the quartz-solution interface in the absence of an activator (Case A) and in the presence of an activator.

of the double layer. Laurate ions cannot approach the surface closely because they will be repelled by the highly negative surface charge, Fig. 11A.

Streaming potential experiments with quartz in solutions of sodium laurate and barium nitrate at pH 10 show that ζ apparently is dependent upon the pH and concentration of barium nitrate. If there had been specific adsorption of laurate ions at the quartz surface in these experiments, ζ would have become more negative upon increase of the concentration of sodium laurate, but this has not been observed. Thus adsorbed laurate ions are probably held next to the surface of barium-activated quartz only by association with specifically adsorbed barium ions in the Stern layer. On the basis of this mechanism, only multivalent cations can function as activators in the soap flotation of quartz. Fig. 11B illustrates the structure of the solid-solution interface of barium-activated quartz in the presence of sodium laurate based on the above reasoning. Such an ionic distribution as shown may result from forces similar to those causing ionic association in solution.

Depression of quartz at high pH values cannot result from competition of hydroxyl ions and oleate ions for the surface, since this experimental work has shown that hydroxyl ions and oleate ions function in different manners at the quartz surface. Thus the adsorption of one at the surface can be affected by the presence of the other, but they are not competing reactions by any means. Depression must then occur by competition between sodium ions and barium ions for space in the Stern layer.

Summary and Conclusions

By means of streaming potential studies the Gouy and Stern concepts of the electrical double layer have been applied to the flotation of quartz. From this work the following conclusions can be drawn:

1—Quartz is negatively charged in pure water. 2—Hydroxyl and hydrogen ions appear to function as potential-determining ions in water. 3—Since pH determines the total double layer potential of quartz, the pH of the solution will affect the adsorption of all other ions by quartz. 4—Sodium ions function as surface-inactive counter ions. 5—Barium ions and aluminum ions function as counter ions and also are attracted to the surface by chemical forces. 6—In the absence of an activator, the only effect of adding sodium laurate or sodium oleate to the system is to compress the double layer. In the presence of an activator, laurate ions are associated with chemisorbed barium ions at the Stern layer.

Acknowledgments

The authors wish to acknowledge the help given them by their associates at the Massachusetts Institute of Technology, especially by J. Th. G. Overbeek, presently of the University of Utrecht, Netherlands, and P. L. de Bruyn. This work was carried out by the generous support of the U. S. Atomic Energy Commission.

References

[1] A. M. Gaudin, H. Glover, M. S. Hansen, and C. W. Orr: *Flotation Fundamentals, I.* University of Utah *TP 1* (1928) p. 78.
[2] A. W. Fahrenwald and J. Newton: *Engineering and Mining Journal* (1937) 138, p. 23.
[3] A. M. Gaudin and A. Rizo-Patrón: *Trans.* AIME (1943) 153, p. 462.
[4] S. R. B. Cooke: *Trans.* AIME (1949) 184, p. 299.
[5] S. R. B. Cook and M. Digré: *Trans.* AIME (1949) 184, p. 306.
[6] R. Schuhmann, Jr., and B. Prakash: *Trans.* AIME (1950) 187, p. 591.
[7] A. M. Gaudin and C. S. Chang: *Trans.* AIME (1952) 193, p. 193.
[8] A. M. Gaudin, H. R. Spedden, and P. A. Laxen: *Trans.* AIME (1952) 193, p. 693.
[9] G. M. Bell: *The Adsorption of Sodium and Chloride Ions on Quartz.* Sc.D. thesis, Massachusetts Institute of Technology, 1953.
[10] H. Freundlich: *Colloid and Capillary Chemistry*, Chap. 4. Methuen & Co. Ltd., London, 1922.
[11] A. M. Gaudin and S. C. Sun: *Trans.* AIME (1946) 169, p. 347.
[12] W. R. Whitney and J. C. Blake: *Journal of the American Chemical Society* (1904) 26, p. 1339.
[13] H. R. Kruyt: *Colloid Science I*, Chap. 4, 5. Elsevier Publishing Co., New York, 1952.
[14] D. W. Fuerstenau: *Streaming Potential Studies on Quartz.* Sc.D. thesis, Massachusetts Institute of Technology, 1953.
[15] H. B. Bull and R. A. Gortner: *Journal of Physical Chemistry* (1932) 36, p. 111.
[16] J. Th. G. Overbeek and P. W. O. Wijga: *Rec. Trav. Chim.* (1946) 65, pp. 556.
[17] O. G. Jensen and R. A. Gortner: *Journal of Physical Chemistry* (1932) 36, p. 3138.
[18] Supplied by courtesy of H. J. Harwood of Armour & Co., Chicago, Ill.
[19] L. A. Wood: *Journal of the American Chemical Society* (1946) 68, p. 437.

Depth Determinations by Electrical Resistivity

by Harold M. Mooney

DISCUSSION

Frank J. Anderson *(Dragon Cement Co. Inc., Northampton, Pa.)*—The article by Harold M. Mooney is as good a compilation of the various methods in use today as I have seen. It is well presented and the different methods well evaluated.

However, although the evaluation and interpretation are good, I feel that the first paragraph is the key to the entire article, namely, that you have to be able to get results before any interpretation can be made. It is stated that many difficulties are attributable to geology and limitation of method and to careless field work and incompetent interpretation.

My own experience has shown these to be true, but I believe that the character of the overlying medium, clay or overburden in many cases, actually eliminates the use of electrical resistivity. I cite the following example.

In a planned quarry development at our Northampton plant many diamond drillholes provided some indications as to the depth of overburden that would be encountered in stripping. Since the grid was a rather wide-spaced one, it was decided to run electrical resistivity measurements over the entire area and draw the rock-clay profile from the interpreted results. The project was done on both close and widely separated electrode spacing, and at no time was it possible to determine any difference in resistivity; consequently no profile could be drawn for the area.

Although we knew the rock was present at determined depths, none could be located through resistivity measurements. When the area was opened up it was found that the overburden was full of glacial material, largely rounded boulders, and the assumption was then made that the inherent electrical characteristics of both clay and rock were the same, with no resistivity differentiation possible.

If this area had not been previously diamond-drilled and only resistivity measurements had been made, the interpretation might show a depth of clay that would eliminate the area from possible use.

I feel that resistivity has its place in depth determinations, but in many cases it must be used with other methods to provide true pictures of the depth.

Harold M. Mooney *(author's reply)*—I am grateful for Mr. Anderson's kind comments. His main point, that resistivity methods require geologic control, was perhaps inadequately emphasized in the original article. Its importance justifies restatement. His second point, that the methods require a *contrast* in the resistivities of earth materials, is beyond dispute. Our experience with poorly sorted glacial materials confirms his suggestion of high resistivity.

Electrolytic Production of Hydrometallurgical Reagents for Processing Manganese Ores

by J. Bruce Clemmer, Carl Rampacek, and P. E. Churchward

The paper describes a cyclic method for processing manganese ores using sodium sulphate as the basic reagent. Sodium sulphate is electrolyzed in a diaphragm cell to give an anolyte containing sulphuric acid and a catholyte containing caustic soda, a part of which is carbonated in a cyclic manner to form soda ash. The reduced ore is leached with the anolyte to dissolve the manganese and the impurities are precipitated by addition of catholyte. Manganese in the pregnant solution is precipitated as synthetic rhodochrosite with a carbonated catholyte, and sodium sulphate is regenerated. Calcining the manganese carbonate gives a high-grade product and the carbon dioxide is returned to the carbonation step. The results of laboratory tests using cells equipped with synthetic fiber diaphragms and permselective membranes which permit transfer of anions or cations during electrolysis are described.

The article from which the above abstract is reprinted appears in Trans. AIME (1955) 203, p. 51; Journal of Metals (January 1955).

AIME OFFICERS
Leo F. Reinartz, President
Vice Presidents
O. B. J. Fraser Harold Decker A. B. Kinzel
James B. Morrow T. B. Counselman L. E. Elkins
President-Elect, H. DeWitt Smith
Treasurer, G. F. Moulton

AIME STAFF
E. H. Robie, Secretary
Ernest O. Kirkendall, Administrative Asst. Secy.
J. B. Alford, H. N. Appleton, E. J. Kennedy, Jr., Assistant Secretaries. P. J. Apol, Assistant Treasurer
R. E. O'Brien, 808 Newhouse Bldg., Salt Lake City, Field Secretary
C. M. Cooley, Mining Branch Secretary

1955 Annual Meeting

Schedule of Mining Branch Technical Sessions

February 13 to 17, 1955
Conrad Hilton Hotel
Chicago

Sunday, February 13—Afternoon and Evening

MIED—The Teaching of Recent Developments in Mineral Engineering

Monday, February 14—A.M.

Min.—Small Mines Problems
Geol.—Exploration
—Uranium
Geop.—General Geophysical I
Coal—Coal Preparation—Flotation
MIED—Engineering Enrollments
Ind. Min.—Ceramic Raw Materials

Monday, February 14—P.M.

Min.—Open Pit Mining
Geol.—Structural Geology
Geol. and Geop.—General Geophysical II
Coal—Coal Preparation
MBD—Analytical Techniques
—Materials Handling and Operating Control
Ind. Min.—Mineral Aggregates

Tuesday, February 15—A.M.

Min.—Block Caving and Underground Mining Problems
Geol.—Mineral Resources
Coal—Utilization—Carbonization
MBD—Solution and Precipitation I
—Concentration I
MED—Economics I
Ind. Min.—Rare Minerals
—Cement, Lime, and Gypsum

Tuesday, February 15—P.M.

Min., Geol., Geop.—Jackling Lecture—General Session
Coal—Stream and Air Pollution
MBD—Solution and Precipitation II
—Concentration II
MED—Economics II
Ind. Min.—Fillers, Fibers, and Pigments

Wednesday, February 16—A.M.

Min.—Mining Research
Geol. and Geop.—Iron Ore Exploration
Coal—Underground Mining I
MBD—Mill Design Symposium
—Concentration III
MED—Economics III
Ind. Min.—Industrial Waters I

Wednesday, February 16—P.M.

Min.—Drilling Problems
Min., Geol., Geop., MIED—Engineer Training
Geol. and Geop.—Iron Ore Panel Discussion
Geop.—Geophysical Instruments
Coal—Underground Mining II
MBD—Symposium: Planning a Successful Ore Beneficiation Plant
—Concentration IV
MED—Economics IV
Ind. Min.—Industrial Waters II
—Chemical Raw Materials

Thursday, February 17—A.M.

Min.—Stratified Mining
Geol.—General Geology
Coal—Geology I
MBD—Crushing and Grinding
—Solids-Fluids Separation
Ind. Min.—Special Sands and Abrasives I

Thursday, February 17—P.M.

Geop.—Radioactivity
Coal—Geology II
Ind. Min.—Special Sands and Abrasives II

MINING BRANCH TECHNICAL PROGRAM

(Data as of Dec. 15, 1954)

MINING SUBDIVISION

Small Mines Problems

Banner Mining Co. By Allan Bowman, General Manager, Banner Mining Co., Tucson, Ariz.

The Mining of Western Phosphate Rock. By D. L. King, President, San Francisco Chemical Co., Montpelier, Idaho.

Domestic Mining of Strategic Chromite. By John Bley, Manager, American Chrome Co., Nye, Mont .

Open Pit Mining

The Three R's of Open Pit Mining—Repairs, Replacements & Results. By V. E. Fielding, Supt., Isbell Construction Co., Reno, Nev.

What is the Economic Point of Replacement of Pit Equipment in the Southwest? By B. R. Coil, Manager, Miami Copper Co., Miami, Ariz.

Freezeproofing Waste Dump Cars at Kennecott's Utah Copper Mine. By J. C. Landenberger, Jr., General Supt. of Operations, Kennecott Copper Corp., Utah Copper Div., Salt Lake City.

Operations Research From the Operator's Point of View. By H. T. Loehr, Jr., Asst. Mgr.—Engineering, International Minerals & Chemical Corp., Bartow, Fla.

Jackling Lecture

(Joint Session with Geology and Geophysics Subdivisions)

Jackling Lecture: **Mining Technology—Outlook for the Future.** By E. D. Gardner, Chief Mining Engineer, U. S. Bureau of Mines, Washington, D. C.

General

(Joint Session with Geology and Geophysics Subdivisions)

Development and Application of the Small Diameter Wire Line Core Barrel. By V. N. Burnhart, Asst. General Manager, Contract Drilling Div., E. J. Longyear Co., Minneapolis.

The Chollet Project. By M. W. Cox and V. F. Hollister, Geologists, American Smelting & Refining Co., Wallace, Idaho.

Mining Research

Paper by: E. R. Borcherdt, Chief Research Engineer, and L. F. Bishop, Anaconda Copper Mining Co., Butte, Mont.

Mining Research by American Universities. By J. D. Forrester, Dean, School of Mines, University of Idaho, Moscow.

Mining Research in Government Agencies. By Leonard Obert, Chief, Applied Physics Branch, U. S. Bureau of Mines, College Park, Md.

Paper by: J. C. Curtis, Manager, Sales Engineering, Rock Drills, Joy Mfg. Co., Claremont, N. H. and Mr. Calder.

Block Caving and Underground Mining Problems

Friction Drive Mine Hoists. By E. P. Pfleider, Head, Dept. of Mineral Engineering, University of Minnesota, Minneapolis, E. G. Malmlow, Aros Electric Inc., New York City, and Franz Landau, ASEA, Västeras, Sweden.

Electrical Considerations of Friction and Drum Hoists. By R. B. Moore, Manager, Mining Section and A. H. Heulsman, Application Engineer, Mining Section, General Electric Co., Schenectady, N. Y.

Block Caving Plans for the Deep Ruth Mine. By Paul Hett, Asst. General Manager, Kennecott Copper Corp., Nevada Mines Division, McGill, Nev.

The Principles of Caving Used at Climax. By Marvin Stanley Walker, Chief Engineer, Climax Molybdenum Co., Climax, Colo.

Engineer Training

(Joint Session with Mineral Industry Education Division and Geology and Geophysics Subdivisions)

The Minerals Industry Engineer. By J. M. Ehrhorn, Industrial Development Director, U. S. Smelting, Refining & Mining Co., Salt Lake City.

Development of Engineering Talent. By A. C. Thornton, Director of Industrial Relations, International Minerals & Chemical Co., Chicago.

Objects and Results of Training Engineers in the Minerals Industry. By D. C. Houston, Director Industrial Relations, Utah Copper Div., Kennecott Copper Corp., Salt Lake City.

Training Engineers at Climax. By E. J. Eisenach, Climax Molybdenum Co., Climax, Colo.

College Recruit Training Program of Oliver Iron Mining Division. By D. V. Dodge, Oliver Iron Mining Division, U. S. Steel Corp., Duluth.

Drilling Problems

Application of Jackleg Drilling in the Tri-State District. By S. S. Clarke, General Supt. and D. C. Brockie, Tri-State Mines Div., Eagle-Picher Co., Cardin, Okla.

Jet Channeling in Dimension Granite Quarrying. By Ralph A. Fletcher, Jr., and R. M. Carlson, and C. B. Mould, H. E. Fletcher Co., West Chelmsford, Mass.

Energy Relations in Percussion Drilling. By H. L. Hartman, Asst. Prof. Mining, Colorado School of Mines, Golden, Colo. and E. P. Pfleider, Head, Dept. of Mineral Engineering, University of Minnesota, Minneapolis.

Overburden Removal Methods Demarara Bauxite Co., Ltd. By Ralph E. Sinke, General Supt., Demarara Bauxite Co. Ltd., Mackenzie, British Guiana.

Radio Direction Finder for Locating the Bottoms of Bore Holes. By R. P. Corbett.

Stratified Mining

Mining Oil Shale at the Bureau of Mines Experimental Mine. By J. H. East, Jr., Regional Director, Region IV, Bureau of Mines, Denver, and C. K. Rose, Chief, Oil Shale Mining Branch, Region IV, U. S. Bureau of Mines, Denver (Speaker).

Roof Bolting Practice at Westvaco, Wyoming. By Robert F. Love, Asst. Mine Supt., Intermountain Chemical Co., Green River, Wyo.

Blasting Research Leads to New Theories and Large Reductions in Blasting Costs. By Boris J. Kochanoswky, Asst. Professor, Pennsylvania State University, State College, Pa.

Mine Safety. By John J. Reed, Lecturer in Mining, University of California, Berkeley.

A New Use for a Brunton Compass. By Duncan Heron, Asst. Professor, Geology Dept., Duke University, Durham, N. C.

GEOLOGY SUBDIVISION

Exploration

Geological Exploration in Canada's Far North. By Y. O. Fortier, Geologist, Geological Survey of Canada, Ottawa, Ont.

Helicopter Prospecting in the Yukon Territory. By Peter A. Peach, American Metal Co. Ltd., Dept. of Geological Sciences, University of Toronto.

Brazil's Mineral Future. By W. D. Johnston, Jr., Chief, Foreign Geology Branch, U. S. Geological Survey, Washington, D. C.

Philippine Industrial Minerals. By Consorcio G. Roa, Mining Engineer, Bureau of Mines, Manila, Philippines (To be read by Prof. J. Marvin Weller, University of Chicago.)

Mineral Zoning in the Portage Lake Lava District Series, Michigan Copper District. By Richard E. Stoiber, U. S. Geological Survey, Norwich, Vermont and Edward S. Davidson, Grand Junction, Colo.

Structural Geology

(Joint Session with Society of Economic Geologists)

Exploration of Riddle Mountain Nickel Deposits. By A. E. Walker, Geologist, The M. A. Hanna Co., Cleveland.

Anticlinal Control of Ore Deposition. By Dooley P. Wheeler, Jr., Consulting Geologist, Salt Lake City.

Geological, Mineralogical and Crystallographic Factors in the Exploration of Lepidolite Deposits. By E. Wm. Heinrich, Associate Professor, Dept. of Mineralogy, University of Michigan, Ann Arbor, and A. A. Levinson, Asst. Professor, Dept. of Mineralogy, Ohio State University, Columbus.

Alteration & Mineralization in the Irwin District, Gunnison County, Colorado. By A. A. Socolow, Asst. Professor, Dept. of Geology, Boston University.

Tracing Geological Structures by Geochemical Means. By Forbes Robertson, Associate Professor, Dept. of Geology, University of Washington, Seattle.

Mineral Resources

Mineral Resources of the Southeastern States. By Robert A. Laurence, Regional Geologist, U. S. Geological Survey, Knoxville, Tenn.

Future Mineral Resources of Arizona and Nevada. By W. W. Simmons, Chief Geologist, Miami Copper Co., Miami, Ariz.

Latent Mineral Wealth in the Pacific Northwest. By Ralph A. Watson, Geologist, Great Northern Railway, Seattle.

Future Mineral Possibilities of the Central Rocky Mountain Region. By Malcolm B. Kildale, Chief Geologist, International Smelting & Refining Co., Salt Lake City.

Uranium

Uranium Occurrences in the Eastern United States. By Thomas N. Walthier, Division of Raw Materials, AEC, New Providence, N. J.

Recent Uranium Developments in Ontario. By J. D. Bateman, Chief Geologist, Ventures Ltd., Tortonto.

Uranium Deposits in the Black Hills. By John W. King, Chief, Hot Springs Sub-Office, Hot Springs, S.D.

Uranium from the Florida Leached Zone. By James A. Barr, Jr., Asst. Director, Domestic Production, Division of Raw Materials, AEC, Washington, D. C.

Geologic Considerations in Atomic Waste Disposal. By John M. Warde, Head Ceramic Laboratory and Consulting Geologist, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Iron Ore Exploration

(Joint Session with Mining and Geophysics Subdivisions)

The Inductive Electromagnetic Method as Applied to Iron Ore Exploration. By Stanley H. Ward, Chief Geophysics Section, McPhar Geophysics Ltd., Gerald J. Anderson, Michigan District Geologist, E. Richard Randolph, and Rolland L. Blake, The Cleveland-Cliffs Iron Co., Ishpeming, Mich.

Geological Occurrence of Iron Ore in Nevada. By Victor E. Kral, Ford Motor Co., Detroit, Michigan and Robert G. Reeves, Geologist, U.S. Geological Survey, Reno, Nev.

Some Aspects of Iron Ore Exploration in the Western United States. By A. E. Granger, Geologist, AEC, Grand Junction, Colo.

Panel Discussion—Iron Ore

(Joint Session with Geophysics Subdivision)

Exploration for Replacement Deposits of Iron Ore in the Iron Springs District, Utah. By J. Hoover Mackin, Dept. of Geology, University of Washington, Seattle.

W. G. Wahl, Consulting Geologist, Bethlehem Steel Co., Bethlehem, Pa.

Wm. B. Agocs, Chief Geophysicist, Aero Service Corp., Philadelphia.

G. R. Johnson, Geophysicist, Radar Explorations Co., Toronto.

Sam G. Sargis, Magnetic Geophysicist, Geneva Steel Co., Salt Lake City.

Lloyd Schofield, Duluth, Minn.

A. B. Moss, Geologist, Iron Ore Co. of Canada, Montreal.

J. Hoover Mackin, Dept. of Geology, University of Washington, Seattle.

General Geology

Mineralogenic Epochs and Provinces. By Chas. H. Behre, Jr., Professor of Geology, Columbia University, New York City.

Collapse Features at Temple Mountain, Utah. By P. F. Kerr, Professor of Mineralogy, Dana R. Kelley and Marc W. Bodine, Jr., Dept. of Geology, Columbia University, New York and W. Scott Keys, Geologist, AEC.

A New Method of Diamond Drill Core-Sludge Sample Evaluation. By Glenn C. Waterman, Chief Geologist, Chile Exploration Co., Chuquicamata, Chile.

Gravimetric Mapping of Deeply Buried Structure in Mineral Exploration. By Harold O. Seigel, Consulting Geophysicist, Toronto.

GEOPHYSICS SUBDIVISION

General Geophysical I

Results from Airborne Geophysical Methods, Electromagnetic, Radioactive and Magnetic. By Hans Lundberg, President, Lundberg Explorations, Ltd., Toronto, Ont.

The Circular Line Electrode in Equipotential Prospecting. By L. O. Bacon, Michigan College of Mining & Technology, Houghton, Mich.

Induced Polarization in a Region of High Resistivity. By Robert G. Van Nostrand, Magnolia Petroleum Co., Dallas, Texas and F. C. Farnham, Baltimore, Md.

Geophysical Investigations in the East Central Portion of Michigan's Upper Peninsula. By Gordon E. Frantti, Copper Range Co., Painesdale, Mich.

The Gravity Meter in Underground Prospecting. By William Allen, Jr., Research Engineer, Phelps Dodge Corp., Douglas, Ariz.

General Geophysical II

(Joint Session with Geology Subdivision)

Geophysical Case History of Marmora Mine. By W. G. Wahl, Consulting Geologist, and S. Lake, Geologist, Bethlehem Steel Co., Bethlehem, Pa.

Geochemical Prospecting In Nyeba District, Nigeria. By H. E. Hawkes, Lecturer, Massachusetts Institute of Technology, Cambridge, Mass.

The Results and Interpretation of a Ground and Helicopter Geophysical Survey of Green Pond, Morris County, N. J. By W. B. Agocs, Chief Geophysicist, Aero Service Corp., Philadelphia.

Geochemical Exploration Work of the United States Geological Survey. By T. S. Lovering, Chief, Geochemical Exploration Section, U. S. Geological Survey, Denver.

Colorado Plateau Geophysical Studies. By R. A. Black, U. S. Geological Survey, Grand Junction, Colo.

Geophysical Instruments

(Joint Session with Mining and Geology Subdivisions)

Magnetic Gradiometer—Uses and Limitations. By Milton Glicken, Geophysicist, Fairchild Aerial Surveys Inc., Los Angeles.

Magnetic Storm Monitor. By W. E. Wickerham, Research Engineer, Gulf Research & Development Co., Pittsburgh.

Nuclear Induction Magnetometer. By Martin E. Packard, Research Dir., and R. H. Varian, President, Varian Associates, Palo Alto, Calif.

The Application of the High Frequency Reflection Seismic Technique to Near Surface Structural Problems. By Norman Harding, Geologist, Houston Technical Laboratories, Houston, Texas, and Robert Graebner, Seismologist, Geophysical Service Inc., Dallas.

Possibilities of the Shallow-Reflection Seismograph. By D. R. Mabey, L. C. Pakiser, and R. E. Warrick, U. S. Geological Survey, Salt Lake City.

Notes on Seismic Dam Site Studies. By Dart Wantland, U. S. Bureau of Reclamation, Denver.

Radioactivity

Notes on Interpretation of Radiometric Anomalies. By H. Wayne Hoylman, Cons. Geophysicist, Los Angeles.

Statistical Analysis of Variations in Black Shale Radioactivity as a Function of Sample Spacing. By H. A. Slack and W. C. Krumbein, Dept. of Geology, Northwestern University, Evanston, Ill.

Aerial Prospecting for Radioactive Minerals. By G. S. Levy, Measurement Engineering Ltd., Arnprior, Ont.

Radioactivity Prospecting Research. By M. E. Denson, Chief, Geophysical Research & Development Sec., AEC, Denver.

Natural-State Core Studies of Uranium-Bearing Rocks. By G. E. Manger, U. S. Geological Survey, Washington, D. C., G. L. Gates, U. S. Bureau of Mines, San Francisco, and R. A. Cadigan, U. S. Geological Survey, Grand Junction, Colo.

COAL DIVISION

Coal Preparation—Flotation

Effect of Flocculents on Coal Sedimentation. By S. C. Sun, Pennsylvania State University.

Possibility of Increasing Coal Flotation-Cell Capacities is Indicated in Semi-Commercial Scale Experiments. By B. W. Gandrud and H. L. Riley, U. S. Bureau of Mines, Fuels Technology Div., University, Ala.

Flotation of High-Sulphur Coal. By S. C. Sun, Pennsylvania State University.

Coal Preparation

The Main Qualities of a Good Installation of Coal Preparation. By L. Mohier, Industrial Preparation of Combustibles Society, Fontainebleau, France.

The Application of the Vacuum Filter in the Coal Washing Circuit. By J. Apotheker, and D. A. Dahlstrom, The Eimco Corp.

Utilization—Carbonization

Low-Temperature Carbonization of Lignite and Non-Coking Coals in the Entrained State. By V. F. Parry, E. O. Wagner, and W. S. Landers, U. S. Bureau of Mines, Denver, Colo.

Pressure Gasification of Pulverized Coal for Pipeline Gas Production. By C. G. von Fredersdorff, E. J. Pyrcioch, and E. S. Pettyjohn, Institute of Gas Technology.

Agglomeration of Fine Sized Ores with Low Temperature Coke. By C. E. Lesher, Consulting Engineer, Pittsburgh.

Stream and Air Pollution

Application and Economics of Slime Removal for Closed Water Circuits. By D. A. Dahlstrom, and C. E. Silverblatt, The Eimco Corp.

Sealing Mine Refuse Piles with Refuse Fines. By E. G. Graf, G. P. Mazie, and J. W. Myers, U. S. Bureau of Mines, Pittsburgh.

Truth and Fallacy Regarding Acid Coal Mine Drainage. By S. A. Braley, Mellon Institute of Industrial Research, Pittsburgh.

Underground Mining I

A Study of Problems Encountered in Multiple-Seam Coal Mining. By David T. Stemple, Virginia Polytechnic Institute.

A Preliminary Report on Underclay Squeezes in Coal Mining. By W. Arthur White, Illinois Geological Survey.

Underground Mining II

Physical Conditions and Their Effect in Planer Mining. By Stephen Krickovic, Eastern Gas & Fuel Association, Pittsburgh, Pa.

Dry Dust Collecting with Rotary Drilling. By C. William Parisi, Pittsburgh Coal Co., Library, Pa.

Geology I

(Joint Session with Society of Economic Geology)

Locating Quaternary Cutouts in Coal by Seismic Refraction Method. By Charles E. Weir and Maurice E. Biggs, Indiana State Geological Survey.

Strippable Coal Reserves in the Fort Union Region of Montana and North Dakota. By W. C. Culbertson, U. S. Geological Survey, Tuscaloosa, Ala.

Behavior of Petrographic Components of North Dakota Lignite in Preparation, Low-Temperature Carbonization, and Steam-drying. By Alfred Traverse, U. S. Bureau of Mines, Grand Forks, N. D.

Microscopic Studies of Uranium-Bearing Coal Deposits. By J. M. Schopf and R. J. Gray, U. S. Geological Survey, Columbus, Ohio.

Geologic Studies of Coal Mine Roof Shales. By J. A. Simon, Illinois State Geological Survey.

The Origin of Ash-Forming Ingredients in Coal. By Maurice Deul, U. S. Geological Survey, Washington, D. C.

Geology II

(Joint Session with Society of Economic Geologists)

The Isotopic Geochemistry of Carbon. By Harmon Craig, University of Chicago.

A Summary of the Stable Carbon Isotopes in Humic and Sapropelic Sediments Throughout the Geologic Column. By Kalervo Rankama, University of Helsinki.

Symposium on Differential Thermal Analysis

Studies of Carbonaceous Materials by Vacuum Differential Thermal Analysis. By I. A. Breger, U. S. Geological Survey.

Some Experimental Factors that Modify Differential Thermograms of Bituminous Coals. By K. E. Clegg, Illinois State Geological Survey.

Investigation of the Coking Properties of Coal by Vacuum Differential Thermal Analysis. By L. H. King, Geological Survey of Canada, and D. G. Kelley, Massachusetts Institute of Technology.

(Panel discussion on differential thermal analysis of coal and carbonaceous materials)

MINERALS BENEFICIATION DIVISION

Analytical Techniques

Quantitative Use of X-ray Diffraction for Analysis of Iron Oxides in Gogebic Taconite of Wisconsin. By R. S. Shoemaker, Electro Metallurgical Co., and D. L. Harris, University of Wisconsin.

Comminution Calculations. By F. C. Bond, Allis-Chalmers Mfg. Co.

Rapid Method to Rate Reduction Ratios from Screen Analyses. By A. Legsdin, Missouri School of Mines, and F. L. Schenck, Arabian American Oil Co.

Microscopic Identification and Mineral Analysis. By B. H. McLeod, The Dorr Co.

Materials Handling and Operating Control

Ore Sampling—Art or Science. By S. L. Smith, University of Arizona, and B. H. Irwin, Colorado School of Mines Research Foundation.

The Gravity Flow of Bulk Solids. By Norman F. Schulz, Minnesota Mines Experiment Station.

Handling Difficult Flotation Froths. By W. H. Reck, Western Machinery Co.

Application of the Inclined Rock-Over Skip for Open Pit Haulage. By J. S. Seawright, National Iron Co.

Solids-Fluids Separation

Flocculation of Mineral Suspensions with Coprecipitated Polyelectrolytes. By M. E. Wadsworth and I. B. Cutler, University of Utah.

Theory and Application of Polyelectrolytes to Flocculation. By R. A. Ruehrwein, Monsanto Chemical Co.

Use of Surface Active Agents in Filtration of Flotation Concentrates. By S. C. Sun, D. R. Mitchell, and W. L. Deppe, Pennsylvania State University.

The Eimco Burwell Filter—A Mechanized Plate and Frame Filter. By R. B. Thompson and D. A. Dahlstrom, Eimco Corp.

Solution and Precipitation I

(Joint Session EMD and MBD)

A Kinetic Study of the Oxidation of Sphalerite. By J. N. Ong, Jr., M. E. Wadsworth, and W. M. Fassell, Jr., University of Utah.

Acid Pressure Leaching of Uranium Ores. By F. A. Forward and J. Halpern, University of British Columbia.

A Reaction Rate Study of the Solution of Cuprite in Sulphuric Acid. By M. E. Wadsworth and D. R. Wadia, University of Utah.

Mechanism and Rate of Dissolution of Chalcocite in Acid Ferric Sulphate. By C. O'Neill and N. Arbiter, Columbia University.

Solution and Precipitation II

(Joint Session EMD and MBD)

Metal Precipitation from Salt Solution by H. Reduction. By F. A. Schaufelberger, Chemical Construction Corp.

Beaverlodge Hydrometallurgical Plant. By R. W. Mancantelli and J. R. Woodward, Eldorado Mining & Refining, Ltd

Agitation Versus Process Results in a Zinc Dust Purification. By L. A. Painter and R. K. Carpenter, American Zinc Co. of Illinois.

Nickel-Cobalt Separation by Selective Reduction. By F. A. Schaufelberger, Chemical Construction Corp., and T. K. Roy, Jadavpur College, Calcutta, India.

Concentration I

Iron Ore Flotation at Humboldt. By R. R. Smith, Cleveland Cliffs Iron Co.

An Agglomeration Process for Iron Ore Concentrates. By W. F. Stowasser, Allis-Chalmers Mfg. Co.

Climax Milling Methods. By Max Dessau and Frank Windolph, Climax Molybdenum Co.

The Development of Metallurgical Practices At Tsumeb. By J. P. Ratledge, J. H. Boyce, and J. N. Ong, Tsumeb Corp. Paper to be presented by L. H. Lange.

Concentration II

Problems in Flotation Rate Studies. By N. Arbiter, Columbia University.

The Effect of Impeller Speed and Air Volume on the Flotation Rate. By W. E. Horst, Foote Mineral Co., and T. M. Morris, Missouri School of Mines.

Depolarizing of Magnetite Pulps. By L. G. Hendrickson and M. F. Williams, Oliver Iron Mining Div., U. S. Steel Corp.

Types of Commercial Wet Magnetic Separators and Their Application to Mineral Dressing. By T. K. Maki, Dings Magnetic Separator Co., and Ed Furness, Reserve Mining Co.

Concentration III

Desliming and Preliminary Concentration of Slimy Ores with Ultrasonics. By S. C. Sun, Pennsylvania State University.

Streaming Potential Studies—Quartz Flotation with Anionic Collectors. By A. M. Gaudin and D. W. Fuerstenau, Massachusetts Institute of Technology.

Flotation of Quartz by Cationic Collectors. By P. L. deBruyn, Massachusetts Institute of Technology.

Adsorption of a Mercaptan on Zinc Minerals. By A. M. Gaudin, Massachusetts Institute of Technology, and D. L. Harris, University of Wisconsin.

Concentration IV

Substituted Starches in Amine Flotation of Iron Ore. By C. S. Chang, Chemical Construction Co.

Adsorption of Dodecylammonium Acetate on Hematite and Its Flotation Effect. By A. M. Gaudin and J. G. Morrow, Massachusetts Institute of Technology.

Flotation and the Gibbs Adsorption Equation. By P. L. deBruyn, Massachusetts Institute of Technology, J. Th. G. Overbeek, University of Utrecht, and R. Schuhmann, Jr., Purdue University.

Some Physico-Chemical Aspects of Flotation. By C. C. DeWitt, Michigan State College.

Mill Design Symposium

Drafting, Construction Models and Visual Aids. By Frank Pettit, Associated Engineers, Inc.

Designing Ore Treatment Pilot Plants. By R. D. Macdonald and F. M. Stephens, Battelle Memorial Institute.

Design of Tubular Conveyor Galleries. By H. L. Tamplin, D. E. Bourke, and L. Ratnik, General Engineering Co., Inc.

Layout of Grinding Floors. By D. J. Drinkwater, Mine & Smelter Supply Co.

MBD Continued

Crushing and Grinding

Power Correlation for Rod Mills. By P. K. Guerrero, University of Philippines, and N. Arbiter, Columbia University.

Correlation Between Principal Parameters Affecting Mechanical Ball Wear. By H. T. Hukki, Finland Institute of Technology. Paper to be presented by F. C. Bond, Allis-Chalmers Mfg. Co.

The Significance of Speed of Tumbling Mills on their Capacity and Power Consumption. By H. T. Hukki, Finland Institute of Technology. Paper to be presented by F. C. Bond, Allis-Chalmers Mfg. Co.

Analysis of Rod Milling Variables—Comparison of Overflow and End Peripheral Discharge Mills. By Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom, Allis-Chalmers Mfg. Co.

Some Pitfalls in Dust Control in Ore Conditioning and Crushing Plants. By R. T. Wilson, Tennessee Coal & Iron Div., U. S. Steel Corp.

Symposium: Planning A Successful Ore Beneficiation Plant

What information should the metallurgical engineer obtain from the Geology and Mining Department to do a good job of testing? By S. R. Zimmerley, Kennecott Copper Corp.

What information should the metallurgical engineer give the mill designer? By Frank Briber, Stearns-Rogers Mfg. Co., and Jess Carlile, J. C. Carlile & Associates.

What is the responsibility of the equipment manufacturer in mill design? By Kellogg Krebs, Equipment Engineers, Inc.

What does the operator expect of the research department on metallurgical results and of the mill designer on design? By W. A. Hamilton, White Pine Copper Co., and O. M. Wicken, Foote Mineral Co.

Some suggestions on how the operator, mill designer, metallurgical engineer, and contractor can work together. By C. Marsh, National Lead Co.

What is a good construction contract? By W. Howes, Western-Knapp Engineering Co., and E. C. Herkenhoff, Pickands Mather & Co.

INDUSTRIAL MINERALS DIVISION

Ceramic Raw Materials

Mining and Processing of Bentonite in the Black Hills, South Dakota (16 mm. film and commentary). By A. G. Clem, American Colloid Co., Chicago.

The Synthesis and Properties of Large Single Crystals of $SrTiO_3$. By Leon Merker, National Lead Co., South Amboy, N. J.

Ceramic Raw Materials from Hydrothermally Altered Volcanic Rocks. By Oliver Bowen, Jr. and Melvin G. Stinson, California Div. of Mines, San Francisco.

Diaspore, Flint, and Plastic Fireclay Reserves of Missouri. By F. G. Mertens, Laclede-Christy Co., St. Louis.

Staurolite—New Industrial Mineral. By C. H. Evans, Engineering Service Division, E. I. du Pont de Nemours & Co., Wilmington, Del.

Mineral Aggregates

Sand and Gravel Aggregates of Wisconsin. By G. F. Hanson, Wisconsin State Geologist, Madison, Wis.

Sand and Gravel Aggregates of Illinois. By J. E. Lamar, Illinois State Geological Survey, Urbana.

Size Distribution and Lithologies of Indiana Gravels. By Duncan J. McGregor, Indiana Geological Survey, Bloomington, Ind.

The Blast Furnace Slag Industry of the United States. By E. W. Bauman, National Slag Assn., Washington, D. C.

Production Problems of the Stone Industry and Needed Research. By Nelson Severinghaus, Consolidated Quarries Corp., Decatur, Ga.

Developments in the Field of Explosives as Related to the Production of Mineral Aggregates. By D. M. McFarland, Atlas Powder Co., Wilmington, Del.

The Manufacture and Use of Heavy Fired Clay and Shale Aggregates. By Norman Plummer, Kansas Geological Survey, Lawrence.

Rare Minerals

That Atom—Lithium. By L. G. Bliss, Foote Mineral Co., Philadelphia.

Lithium Resources of North America. By James J. Norton and Dorothy McKenney Schlegel, U. S. Geological Survey, Denver, Colo.

Geology of the Kings Mountain Spodumene District, North Carolina. By W. R. Griffitts, U. S. Geological Survey, Washington, D. C.

Aspects of the Mining and Concentration of Spodumene from the Pegmatites of the Black Hills, South Dakota. By Fremont F. Clarke and Gerald A. Munson, Lithium Corp. of America, Minneapolis.

Extraction of Lithium from its Ores. By Fremont F. Clarke and R. B. Ellestad, Lithium Corp. of America, Minneapolis.

Cement, Lime, and Gypsum

Raw Material Preparation at the Brandon, Miss. Plant. By Jens C. Holm, Marquette Cement Mfg. Co., Chicago.

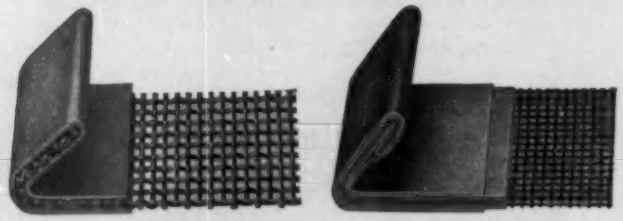
Lime Recovery and Conservation. By W. H. Tock, Allis-Chalmers Mfg. Co., Milwaukee.

Human Response to Industrial Blasting Vibrations. By Jules E. Jenkins, Vibration Measurement Engineer, Chicago.

New Thornton Dolomite Plant. By L. H. Niems, Marblehead Lime Co., Thornton, Ill.

Quarry Operation, with Emphasis on Heavy Stripping. By John B. Pitts, Jr., National Gypsum Co., Fort Dodge, Iowa.

Tyler Screen Sections for All Makes of Screening Machines!



Screen sections of Tyler Woven Wire are fabricated for all makes of vibrating screens in any mesh or metal. They are made up with hook-strip or bent-edge construction to suit the machine on which they are to be used.

Tyler rugged, accurately-applied hook-strips make possible stretching and maintaining the screens at drum-head tension, which is essential for successful screening and long screen life.

THE W. S. TYLER COMPANY
CLEVELAND 14, OHIO
Manufacturers of Woven Wire Screens and Screening Machinery

Canadian Plant—St. Catharines, Ontario, Canada

Fillers, Fibers and Pigments

Fullers Earth Industry in the Florida-Georgia District. By James L. Calver, Florida Geological Survey.

Pigments—A General Survey, with Special Reference to Titania. By L. R. Blair, Johns-Manville Co., Manville, N. J.

A New Use for Barytes. By Walter F. Winters, Rubarite, Inc., Chicago.

Ball Clay Mining in the United States. By Richard Bell, Bell Clay Mining Co., Gleason, Tenn.

The Requirements of Modern Paper Clays. By C. G. Albert, Minerals & Chemical Corp. of America, Metuchen, N. J.

Quality Control of Wollastonite. By C. H. Pratt, Cabot Minerals Div., Willsboro, N. Y.

Chemical Raw Materials

Industrial Limestones in the Southern Appalachian Region. By Byron N. Cooper, Geologist, Blacksburg, Va.

The Future of Industrial Limestone and Dolomite in the Midwest. By Kenneth A. Gutschick and John Peter Flynn, Pit & Quarry Publications, Chicago.

Mexican Sulphur Developments. By Harold H. Jaquet, Pan American Sulphur Co. de Mexico, S. A. Jaltipan, Vera Cruz, Mexico.

The Barite Industry. By B. C. Elsley, Baroid Sales Div., National Lead Co., Houston.

Rare Earth Minerals in Industry. By Frank D. Lamb, U. S. Bureau of Mines, Washington, D. C.

Industrial Waters I

Groundwater Geology in Industrial Expansion and Decentralization. By John W. Foster and John C. Frye, Illinois Geological Survey, Urbana, Ill.

Water Quality and Industrial Uses. By John E. Tarman, Consulting Div., W. H. and L. D. Betz, Philadelphia.

Problems of the Mineral Industry Arising from Water Resources and Flood Control Development. By L. W. Dupuy, U. S. Bureau of Mines, Washington, D. C.

Evaluation of Rain Making and Weather Modification Techniques. By H. T. Orville, Bendix Aviation Corp.

Industrial Waters II

Policy and Technical Problems in Water Pollution Abatement. By W. B. Hart, The Atlantic Refining Co., Philadelphia.

A Rational Approach to Water Pollution Control Problems. By Vinton W. Bacon, State Water Pollution Control Board, Sacramento, Calif.

Potential Use of Saline Ground Water in Texas. By William O. George, Ground Water Branch, U. S. Geological Survey, Austin, Tex.

Demineralization of Brackish Waters by the Electric Membrane Method. By Thomas A. Kirkham, Ionics Inc., Cambridge, Mass.

Special Sands and Abrasives I

Industrial Sands and Abrasives in the Southern Mid-Continent Region. By William E. Ham, Oklahoma Geological Survey, Norman.

Flotation of Del Monte Sands. By W. E. Messner (deceased) read by Hugh H. Bein, Del Monte Properties Co., (Sand Div.), Pacific Grove, Calif.

Sand Usage in Hydraulic Fracturing Oil Bearing Formations. By W. E. Hassebroek, Halliburton Oil Well Cementing Co., Duncan, Okla.

Special Sands and Abrasives II

High Purity Silica Resources of Southeastern United States. By Thomas D. Murphy, U. S. Geological Survey, Washington, D. C.

Eastern Bonded Sands. By Robert J. Maddison, Whitehead Bros. Co., New York.

Application of the Phi Scale to the Description of Granular Materials. By Charles H. Bowen, The Ohio State University, Columbus, Ohio.

Michigan Bank Sands. By Warren D. Lewis, Great Lakes Foundry Sand Co., Detroit.

MINERAL INDUSTRY EDUCATION DIVISION

The Teaching of Recent Developments in Mineral Engineering

The MIED in Retrospect and its Recent Developments. By E. A. Holbrook, Dean Emeritus, University of Pittsburgh.

The Teaching of Recent Developments in Mining Engineering. By Philip B. Bucky, Prof. Min. Engrg., Columbia University.

The Teaching of Recent Developments in Mineral Dressing. By T. M. Morris, Assoc. Prof. Met. Engrg., University of Missouri.

Evening Session

The Teaching of Recent Developments in Physical Metallurgy. By T. A. Read, Prof. Met. Engrg., Univ. of Illinois.

The Teaching of Recent Developments in Petroleum Production Engineering. By Clark F. Barb, Prof. Petroleum Engrg., Colorado School of Mines.

Enrollments

Report on Mineral Engineering Enrollments. By W. B. Plank, Prof. Min. Engrg., Emeritus, Lafayette College.

Reasons and Incentives for Pursuing a Career in the Mineral Industries. By J. J. Schanz, Dept. Mineral Economics, Pennsylvania State Univ.

MINERAL ECONOMICS DIVISION

Economics I

Introduction of New Officers

Present Status of "Handbook on Mineral Economics"

Unsolved Economic Problems in Utilization of Minerals. By David Swan, Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N. Y.

Research—Challenge and Opportunity to the Mineral Industry. By Richard J. Lund, Battelle Memorial Institute, Columbus, Ohio.

Economics II

Economic Patterns of Coal Utilization. By T. W. Hunter, Chief, Coal Branch, U. S. Bureau of Mines.

Some Effects of Oil Imports on the Petroleum Industry and Their Implications. By H. J. Barton, Petroleum and Natural Gas Economic Coordinator, U. S. Bureau of Mines.

The Advantages of Common over Private Carrier Transportation. By John M. Poorman, Kenneth Poorman Co., Portland, Ore.

St. Lawrence Seaway and the Mineral Industries. By A. J. Boynton, A. J. Boynton & Co., Chicago.

Economics III

Iron Ore Supply for Atlantic Basin Nations. By Walter H. Voskuil, Mineral Economist, State Geological Survey, Urbana, Ill.

Patterns of International Trade in Metal Raw Materials. By John Drew Ridge, Head of Dept. of Mineral Economics, Pennsylvania State University.

Principles of Mineral Economics Engendered by the Income Tax. By Granville S. Borden, Standard Oil Co. of California, San Francisco.

Economics IV

Program of Defense Minerals Exploration Administration. By C. O. Mittendorf, Administrator, DMEA U. S. Dept. of the Interior, Washington, D. C.

Critical Strategic Minerals in the Western Hemisphere. By Senator George W. Malone and George B. Holderer.

Mineral Policies and Programs of the U. S. Government. By John D. Morgan, Jr., Mineral Expert, Office of Defense Mobilization, Washington, D. C.

Citations for Annual Meeting Awards Announced

The following citations have been prepared for those to whom awards will be given at the AIME Annual Meeting in February 1955:

George Herman Deike, Erskine Ramsay Medalist: "As an engineer, manufacturer, and executive, Mr. Deike has served the mining industry with distinction in many ways, particularly in the field of mine safety. His pioneering work in the application of engineering principles in reducing the dangers inherent in mining has earned for him an international reputation. Under his direction as an administrator, inventor, and manufacturer of safety appliances, his company has become preeminent in the manufacture of industrial safety equipment. He has been a leader in the application of scientific research in the promotion of safety and efficiency in industry. His company recently dedicated the world's largest research center devoted exclusively to the development of safety equipment. This laboratory, one of the most modern of its kind, symbolizes his basic philosophy—'keep ahead of safety needs in the mining industry.' Mr. Deike, with all his business responsibilities, has always taken a very active part in civic and community activities, and his genial personality and his humane qualities have endeared him to his host of friends everywhere."

Edwin Letts Oliver, James Douglas Medalist: "Noted for his invention of the Oliver continuous filter—a most outstanding contribution to nonferrous metallurgy and widely applicable to industrial fields throughout the world. A man of far-flung interests, a distinguished engineer and administrator, beloved and respected for assistance given to younger engineers."

Edward W. Davis, Robert H. Richards Award Recipient: "For his inspiring leadership and notable technical contributions in the utilization of taconite as a source of iron ore."

E. D. Gardner, Jackling Award Recipient: "For significant contributions to technical progress in the field of mining, and for his Lecture, *Mining Technology—Outlook for the Future.*

W. G. Pfann, Mathewson Medalist: "For three papers published in the JOURNAL OF METALS: *Principles of Zone Melting, Segregation of Two Solutes, with Particular Reference to Semiconductors,* and *Redistribution of Solutes by Formation and Solidification of a Molten Zone.*

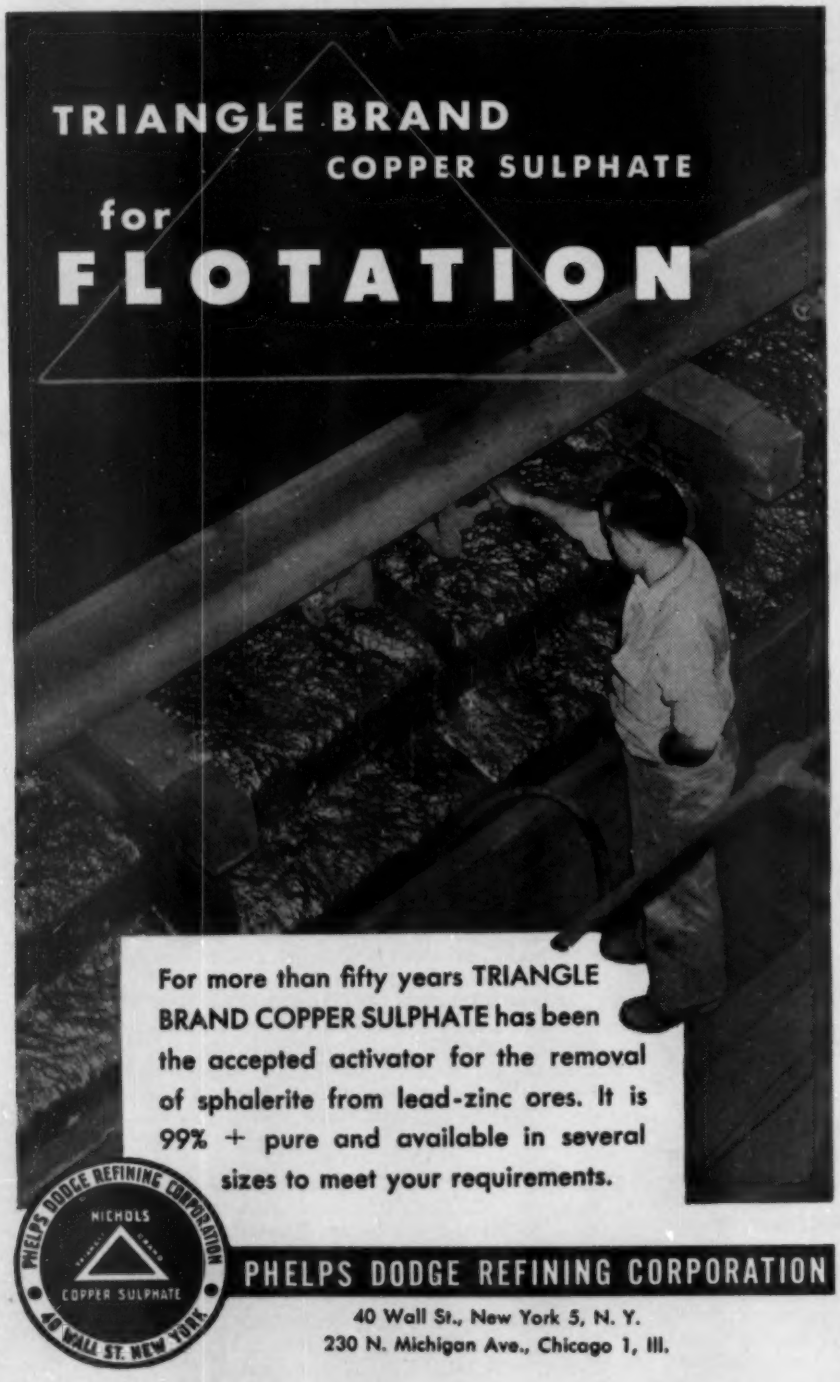
F. W. Boulger and **R. H. Frazier, Robert W. Hunt Medalists:** "For their paper, *The Influence of Carbon and Manganese on the Properties of Semi-killed Hot-Rolled Steel,* published in the Supplement to the JOURNAL OF METALS, May 1954."

Gust Bitsianes, J. E. Johnson Jr. Award Recipient: "For his paper on *The Topochemical Aspects of Iron Ore Reduction* and his other contributions to the literature in the manufacture of pig iron."

Harold Vagtborg Jr., Rossiter W. Raymond Award Recipient: "For his paper, *Equilibrium Vaporization Ratios for a Reservoir Fluid Containing a High Concentration of Hydrogen Sulfide,* published in the JOURNAL OF PETROLEUM TECHNOLOGY."

R. E. Thurmond, W. E. Heinrichs Jr., and **E. D. Spaulding, Robert Peele Award Recipients:** "For their paper, *Geophysical Discovery and Development of the Pima Mine, Pima County, Arizona,* published in MINING ENGINEERING."

In addition to the above, an AIME junior member has been selected to receive the Alfred Noble Prize in 1955, awarded to a junior member of the Founder Societies or the Western Society of Engineers each year for a paper of particular merit. The winner this year was Cornelius S. Roberts for his paper, *Creep Behavior of Magnesium-Cerium Alloys,* published in the May 1954 Supplement to the JOURNAL OF METALS.


TRIANGLE BRAND
COPPER SULPHATE
for
FLOTATION
For more than fifty years TRIANGLE BRAND COPPER SULPHATE has been the accepted activator for the removal of sphalerite from lead-zinc ores. It is 99% + pure and available in several sizes to meet your requirements.
PHELPS DODGE REFINING CORPORATION
NICHOLS
COPPER SULPHATE
40 WALL ST. NEW YORK
PHELPS DODGE REFINING CORPORATION
40 Wall St., New York 5, N. Y.
230 N. Michigan Ave., Chicago 1, Ill.

Pacific Northwest Meeting, Apr. 28 to 30

Plans for the Pacific Northwest Regional Conference to be held in Spokane, Wash., Apr. 28, 29, and 30, 1955, are going forward according to General Chairman, A. Y. Bethune, Sullivan Mining Co., electrolytic zinc plant, Kellogg, Idaho.

S. E. Maddigan, assistant director, dept. of metallurgical research, Kaiser Aluminum & Chemical Co., Spokane, Wash., is Chairman of the Metals Branch activities. Joseph R. Giegerich, superintendent, the Sullivan mine, Consolidated Mining & Smelting Co. of Canada Ltd., Kimberley, B. C. will head up the Mining Branch activities and John P. Spielman, dean, School of Mines, State College of Washington, Pullman, will be in charge of the Mineral Industries Education group. A full program of student participation is planned with one evening set aside for the Educational meeting.

The following division chairmen have accepted commitments and are now working on the various technical programs:

Mining: Joseph C. Kieffer, assistant manager, American Smelting & Refining Co., Wallace, Idaho

Geology: Robert E. Sorenson, chief geologist, Hecla Mining Co., Wallace, Idaho

Minerals Beneficiation: Wm. D. Nesbeitt, manager, the Allis-Chalmers Mfg. Co., Spokane, Wash.

Industrial Minerals: P. Evan Oscarson, mining engineer, 1108 W. 19th Ave., Spokane, Wash.

Extractive Metallurgy: R. J. Lapee, metallurgist, the Anaconda Copper Mining Co., Great Falls, Mont.

Plans are being made for a special session on *X-Ray Fluorescent Analysis*, Saturday, April 30, with particular reference to its applicability to mining, milling, geology, industrial minerals, and ceramic problems. F. R. Morral, X-ray div. chief, dept. of metallurgical research, Kaiser Aluminum & Chemical Corp., Spokane, is in charge.

Research Projects

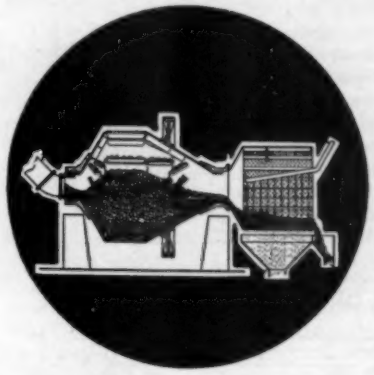
Following endorsement by the AIME, Engineering Foundation has voted support to the following research projects:

Flow of Bulk Solids, by Andrew W. Jenike, Salt Lake City. Dr. Jenike hopes to develop a quantitative method of design for flow of bulk solids in bins, hoppers, chutes, and other material handling equipment. The Minerals Beneficiation Div. of the AIME has given its encouragement to this study. A grant of $5000 by Engineering Foundation has been made contingent on raising an additional $15,000.

The other two projects are of interest to the petroleum industry. One, on **Forces Exerted on Oscillatory Fluid Motion on Cylinders,** has to do with the effect of ocean waves on piles, and is of particular interest in connection with equipment and installations used in offshore drilling for oil. A grant of $1500 has been made to D. L. Laird, of the University of California. The other, **Phenomena Underlying Natural Disasters,** is a proposed study which, if successful, would permit the successful forecasting of tidal waves, or sudden unexpected onrushes of water. This, again, would be of value to offshore drilling crews. A grant of $5000 for this study has been given to William L. Donn, of the Lamont Geological Observatory, Columbia University.

Hobbs Local Section Officially Established

Releases having been secured from local sections a part of whose area has been taken over, the Hobbs Local Section was officially established. The Hobbs Section is an *overlaying* section to the extent that it covers the same ground as part of the Carlsbad Potash Section. Petroleum Branch members in this area of New Mexico (Eddy, Lea, and Chaves Counties) will henceforth be served by the Hobbs Section, and Mining and Metals Branch members by the Carlsbad Section.



What is

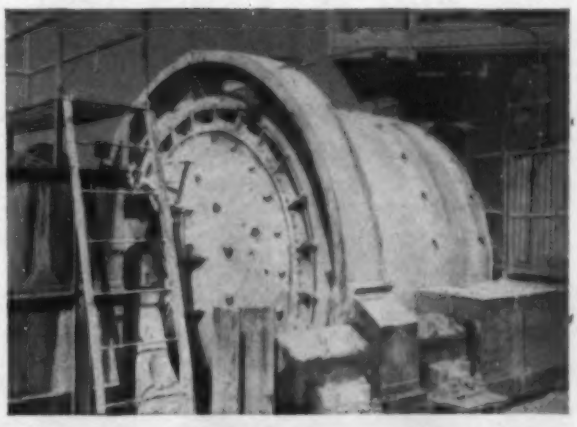
Mass Action

in Ore Scrubbing?

"Mass Action" in a HARDINGE CONICAL SCRUBBER is similar to the effect obtained by rubbing a handful of pebbles between the palms in a stream of water.

This scrubber is capable of removing a very hard clay from ores, phosphate rock, gravel, etc., in a very short time with only nominal wear in the machine itself.

Write for Bulletin 37-A-2 and give us pertinent details of your scrubbing problem.



View of a 10′ x 66″ Hardinge Scrubber cleaning crushed dolomite in a California plant. The trommel screen is at the left.

HARDINGE

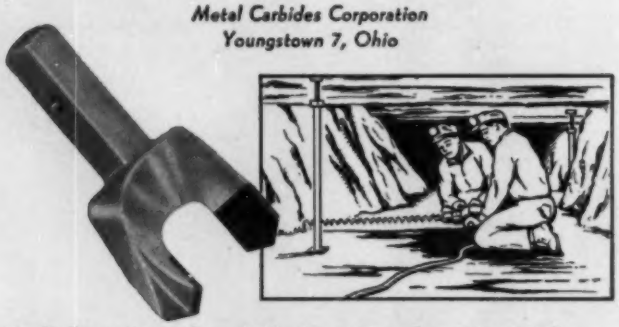
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

New York • Toronto • Chicago • Hibbing • Houston • Salt Lake City • San Francisco

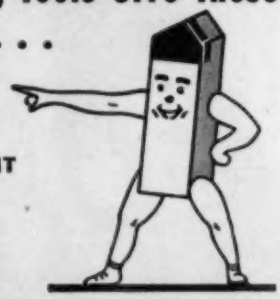
● Mining contractors, ore prospectors, coal operators and construction firms are realizing tremendous savings by taking advantage of our **exclusive fabrication service!** Contractors send us the necessary diamond stones from their own stocks—we hand set them in a super-hard tungsten carbide crown and braze to the threaded steel blank. Hand-set bits assure the proper positioning of each diamond stone to achieve maximum cutting efficiency. The carbide matrix holds the diamond stones until entirely used up. These advantages mean lower drilling costs to you. We can also supply complete core bits or salvage the stones from used bits at nominal cost. Supplied in standard sizes EX, EXE, AX, BX, NX, etc.

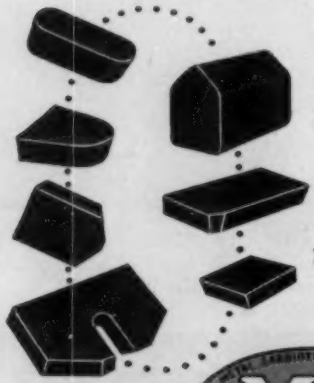
Metal Carbides Corporation
Youngstown 7, Ohio



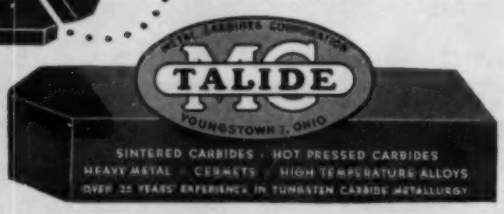
Talide Tips for Mining Tools Give These 3 BIG ADVANTAGES . . .

1. EXTRA STRONG
2. SUPER HARD
3. SHOCK RESISTANT





● A complete line of low-cost, high-quality Talide Tips is offered fabricators and users for tipping machine bits, rock bits, drill bits, roof bits and open-pit bits. All Talide Tips have a special surface finish that facilitates brazing. Non-standard shapes and sizes quoted on request.



Ambrose Monell Medal To Lloyd M. Pidgeon

Lloyd M. Pidgeon, MBE of the University of Toronto, has been named recipient of the first Ambrose Monell Medal for distinguished achievement in mineral technology, it was announced today by Prof. M. D. Hassialis of the Columbia University School of Mines, chairman of the award committee.

Mr. Pidgeon, head of the Dept. of Metallurgical Engineering at the University of Toronto, is discoverer of the Pidgeon Process for production of metallic magnesium. A well-known metallurgist, he was awarded the Monell Medal by a seven-man committee.

The first award committee consists of: Leo F. Reinartz, President, AIME; Charles C. Huston, president, Canadian Institute of Mining and Metallurgy; Brigadier R.S.G. Stokes, president, British Institution of Mining and Metallurgy; Felix Wormser, Assistant Secretary of the Interior; Professor Hassialis; Maxwell Gensamer; and Philip Bucky of the Columbia School of Mines.

The Monell Medal, awarded through the Columbia School of Mines, was presented to Mr. Pidgeon on Tuesday evening, November 16, at ceremonies at the Men's Faculty Club on the Columbia campus.

The triennial Monell Medal was established at the School of Mines in honor of Ambrose Monell by his widow, Mrs. Maude Monell Vetlesen. Mr. Monell, a graduate of the School of Mines, was the first president of International Nickel Co. The copper-nickel alloy, Monel, bears his name.

Mr. Pidgeon, now active in research on production of such metals as titanium and zirconium, spoke on development in this field.

Engineering Societies Library Submits Report

According to the report of the Engineering Societies Library for the fiscal year ended Sept. 30, 1954, 16,817 visitors were served, and 21,278 nonvisitors. Orders for photoprints increased to 4704. Close to 10,000 telephone inquiries were answered and some 4800 written replies to inquiries. A total of some 260,000 words were translated. The number of borrowers decreased owing to a discontinuance of lending periodicals.

The Library now consists of 170,787 volumes, 16,301 maps, and 5,457 searches. One third of the new accessions were gifts, and Director Ralph H. Phelps will welcome offers of books that may be desirable additions. Approximately 1400 periodicals are currently being received.

ECPD Meeting Held in Cincinnati

Engineers Council for Professional Development held its 22d annual meeting in Cincinnati, October 28 to 29, with an attendance of more than 200. The time was not particularly convenient for many AIME members, including some of the officers who were in the West at that time, or attending an important meeting in Pittsburgh. The AIME was, however, represented by C. E. Lawall, J. P. Nielsen, and E. Paul Lange.

Two reports made at the meeting were of particular interest to AIME. One was that of the ECPD Education Committee. The National Council of State Boards of Engineering Examiners had suggested that ECPD accredit curricula only in those schools which confine their faculties to registered professional engineers. The Committee felt that registration should be encouraged for those faculty members for whom it was appropriate or necessary but did not wish to take the position that all faculty members must necessarily be registered professional engineers in order for a curriculum to be accredited. The Committee also recommended that accredited curricula hereafter fall into two groups: Major Engineering Curricula, to include mining and metallurgical engineering, and Cognate Engineering Curricula, which, in the field of AIME, would include, ceramic, geological, geophysical, and petroleum engineering.

President Reinartz is shown with J. H. Melvin, Ohio Geological Survey, Ohio State University, Columbus, Ohio, and H. P. Gaw, Armco Steel Corp., Middletown, Ohio, at the dinner meeting held by the Ohio Valley Local Section.

President Reinartz Visits Ohio Section

Leo F. Reinartz, President of AIME, and his wife were guests of the Ohio Valley Local Section at a dinner meeting held in their honor at the Deshler-Hilton Hotel, Columbus, Ohio. The meeting was attended by 67 members and wives.

Mr. Reinartz, after being introduced to the group by Harold P. Gaw, Section Chairman, discussed some of the problems and policies of AIME. A similar talk, explaining AIME policies, will be given by one of the national officers to each of the local sections of AIME this year.

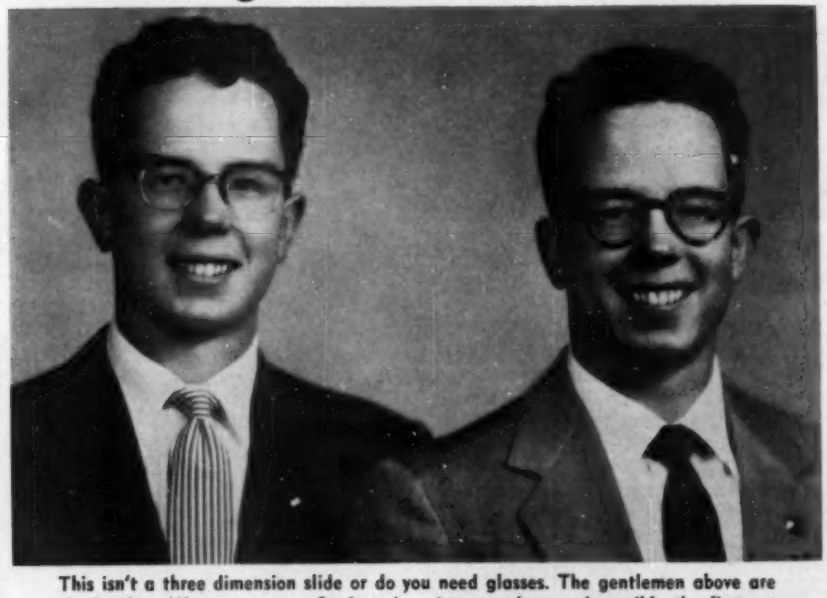
The growth rate of the society was considered to be very good, approximating 1 pct a month. The quality and number of technical papers published, especially by the Metals Branch, is also satisfactory.

The society still has some financial problems. Local section financing has been improved this year by returning one half of all initiation fees back to the local sections. The Metals Branch continues to show a deficit arising from the publication of technical papers. A special fund of $50,000 is being raised to meet some of this cost.

A big problem remaining is to discover how the society and its members can more effectively encourage young people to enter, and remain in, the engineering profession. The United States is graduating fewer engineers this year than is Russia.

A short discussion period concluded the meeting.

AIME Seeing Double?



This isn't a three dimension slide or do you need glasses. The gentlemen above are the brothers Westerman, new Student Associate members and possibly the first set of twins to join the AIME. Edwin J. is on the left and Richard E. is on the right. Both attend the Montana School of Mines and both expect to receive Bachelors of Science in Metallurgical Engineering. Their signatures are for all purposes identical. Right after the Westerman applications were received at headquarters, another set of twins signed in. They were Norman W. and Ramon G. Bentsen, in the June '55 Class at Oklahoma University. They are majoring in petroleum engineering and were born in Alix, Canada.

Consider Trip To Lima in '55

Thought is being given to a trip to Lima, Peru, and the mining districts of that country and Chile, immediately following the Annual Meeting of the AIME in New Orleans in February 1957. The Lima, Peru, Local Section, through its Chairman, Carl Westphal, has invited AIME members to be its guests at that time. Housing accommodations are constantly increasing, and should be adequate two years hence. Travel would presumably be by chartered plane at a cost considerably less than the regular fare. The traditional hospitality of Latin America would be extended to all.

Around the Sections

• Among the busiest AIME groups has been the **Southwestern Alaska Section.** One of the biggest events of the past year was the dinner in honor of Assistant Secretary of the Interior, Felix E. Wormser. Members of his official party were John Reed, Thomas Miller, and S. H. Lorain. The then Chairman Leo Saarela presided at the dinner held at the Idle Hour Country Club. At a later date the first regular meeting of the 1954-55 season was held at the Territorial Dept. of Mines offices, Anchorage. Members discussed the possibility of developing a proposed TV public service program. Further research will be done on the matter. Elections have been held by the section with Martin Jasper named Chairman; Don Wilcox, Vice Chairman; Glenn Chambers, Secretary Treasurer; and Harry Palmer, Hugh Matheson, and Phil Holdsworth, Board of Directors. Harold Strandberg was named Section Delegate.

• M. S. Badollet, section chief in charge of asbestos fibre research for the Johns-Manville Corp., covered the highlights of the asbestos industry, from mineralogy to uses of the finished product, in an hour's talk before the **New York Section,** AIME, at the Mining Club. Sixty pct of the world's production comes from a limited area in Quebec and Ontario. New mines are being opened there, and large new processing plants being built, so that the current problem is for the researchers to find new uses for the product and to stimulate demand for the older uses.

• The **El Paso Metals Section,** meeting at the Hotel Cortez, El Paso, heard Marden W. Hayward speak on *Geology of Some Mines in Mexico and Geology of Paracutin Volcano.* O. Paul Lance, Section Chairman, presided.

• The technical program of a recent meeting of the **Southern New Mexico Section** dealt with the new industrial engineering dept. of Chino Mines Div. of Kennecott Copper Corp. Speakers were J. J. Brubaker, Chino Div. industrial engineer; William McGee and Howard Welmeth, mine industrial engineers; Robert Ganley, mill industrial engineer; and Charles L. Lockart, smelter industrial engineer. Chairman W. H. Goodrich presided over the meeting of 23 members and 4 guests.

• The **Montana Section** held its Annual Meeting last December in the Treasury Room of the Hotel Finlen, Butte. Owen Grinde, assistant advertising director, Montana Power Co., presented a travelogue, *A Color Photo Trip Through Your Treasure State.* The slides accompanying the talk were done by a nationally known photographer.

• The **Southern Sierra Subsection** held another meeting at the Sierra Cafe in Lone Pine, with Lawson Wright, chief engineer of U. S. Vanadium's Pine Creek mine, near Bishop, Calif., as the featured speaker. He described the history of the use of longhole drilling at the mine, problems encountered, and a comparison of percussion and plug diamond drill methods and results. Eleven subsection members attended the meeting.

• The Annual Reminiscence Meeting of the **San Francisco Section** was held in December, with headliners from the Spike Jones and Horace Heidt shows holding forth. Another attraction was a "Cuban bombshell" from the Silver Slipper, Las Vegas.

• The **Colorado Plateau Section** took a winter field trip late last year, with members gathering at the guest house of the Uranium Reduction Co., Moab, Utah. A picnic lunch was served at the Cal Uranium Camp by Merritt K. Ruddock. Mine trips were: Mi Vica mine, Utex Exploration Co.; Little Beaver tunnel and La Salle shaft, Homestake Mining Co.; Continental No. 1 mine, Minerals Engineering Co.; San Juan shaft, Cal Uranium Co.; and Frasier tunnel, Standard Uranium Co.

• The **Central New Mexico Section** came into official existence at an organizational meeting held at the Hilton Hotel, Albuquerque, with 36 members at hand. John A. Wood, Albuquerque, acted as organizer and presided at the meeting. The new section will embrace the largest geographical area in the state and includes the following 18 counties: Bernalillo, Colfax, Guadalupe, Harding, Los Alamos, McKinley, Mora, Quay, Rio Arriba, Sandoval, Santa Fe, San Miguel, San Juan, Socorro, Taos, Torrance, Union, and Valencia. While headquarters of the section will be in Albuquerque, meetings will be rotated among areas of largest membership.

• Walter L. Finlay, vice president and manager of research, Rem-Cru Titanium Inc., spoke on the *High Spots of Titanium Technology in 1954* at a recent meeting of the **Boston Section.** During the business part of the meeting $25 was voted to the MIT Faculty Club Christmas Fund for employees. It was also decided to invite high school science teachers to the meetings in an attempt to interest secondary school students in metallurgy.

• At the Young Engineers Night of the **Chicago Section,** Edward C. Logelin, vice president, U. S. Steel Corp., spoke on *Another Language.* At another meeting, Annual Ladies' Night, Daniel Silverman, Stanolind Oil & Gas Co., discussed *Prospecting for Oil.*

• William F. Hahman spoke on the *Problems Facing the Bituminous Coal Industry and Related Government Mobilization Programs* at a meeting of the **Washington, D. C. Section.** Mr. Hahman was Deputy Administrator of the defunct Defense Solid Fuels Administration and is now special assistant in the Interior Dept. for solid fuels mobilization problems and staff direction of the President's interdepartmental committee for the bituminous coal industry.

•Harry Otto, assistant general manager, Hudson Coal Co., was Chairman of the technical program held at a meeting of the **Pennsylvania Anthracite Section** at the Redington Hotel, Wilkes-Barre, Pa. Papers on the program included: *Introduction and Discussion of the General Water Problems Throughout the Region,* by Mr. Otto; *Southern and Western Middle Field,* by W. C. Muehlhoff, chief engineer, Philadelphia & Reading Coal & Iron Co.; *Eastern Middle Field,* by George Holland, mining engineer, Jeddo-Highland Coal Co.; *Northern Field,* by E. T. Powell, mining engineer, Glen Alden Coal Co.; and *Commonwealth of Pennsylvania's Contribution Toward Solution of the Water Problem,* by Gordon E. Smith, Deputy Secretary of Mines. John T. Griffiths, Hudson Coal Co., was appointed Chairman, Section Membership Committee and Edward A. Lynch, Pottsville, was appointed Chairman, Section Publicity Committee. Edward G. Fox, president, Philadelphia & Reading Coal & Iron Co., was elected Section Delegate for two years. William W. Everett, vice president, Glen Alden Coal Co., was elected Alternate Section Delegate. The next meeting will be held in April. L. D. Lamont, Philadelphia & Reading Coal & Iron Co., will be Chairman of Arrangements. Carroll A. Garner will be Chairman of the Technical Program on Heavy-Media separation.

• Robert Mensing, lubrication engineer, Socony-Vacuum Oil Co. Inc., spoke on lubrication at a meeting of the **St. Louis Section.** He outlined the three current theories of friction, three basic types of friction, and the two basic types of lubrication. He

also discussed types and properties of lubricating oils and their applications. A film, *Service Procedure on Ball Bearings*, brought the program to a close. At a later meeting, a panel developed comparative performance and economics of various methods for conveying materials. Pros and cons of different equipment were covered, pointing out applications for each type of conveyor. On the panel were: F. H. Ehrensperger, Link Belt Co.; A. S. Purmort, Robins Conveyor Div.; T. A. Ruddy, Stephens Adamson Mfg. Co.; J. W. Sherman, St. Joseph Lead Co.; and Roblee B. Martin, Mississippi Lime Co.

• Blizzard conditions blocked the visit of H. De Witt Smith, 1955 President-Elect, and Mrs. Smith to the **Black Hills Section.** Weather closed down the Rapid City Airport. N. Herz, former classmate of Mr. Smith, gave a brief personal sketch of the next AIME head. During the business session these officers for 1955 were announced: Renaldo Gallo, Chairman; Carleton B. Harris, first Vice Chairman; Arthur J. Rice, second Vice Chairman; Francis G. Hoffman, Secretary Treasurer; and William C. Campbell, A. E. McHugh, E. L. Tullis, and Claude Schmidt, members of the Board of Directors.

• Nickel's role in alloyed steels and cast irons used in mining operations was reviewed by O. B. J. Fraser, assistant manager of the Development & Research Div., International Nickel Co., at a meeting of the **Adirondack Section**. Mr. Fraser is a Vice President of the AIME. He said, "Strength and ductility in metals and alloys depend on the intrinsic properties of their constituents and also on the internal structure and distribution of their component grains . . . Steels are basically alloys of iron and carbon containing not over about 1.7 pct of carbon and composed of the two species, iron or ferrite, and iron carbide or cementite." He also stated that while nickel can be the only alloying metal in a steel or iron, there is a large use of more complex compositions containing significant amounts of other elements. One special class of alloys having considerable interest in mining and milling practice is composed of the highly alloyed chromium-nickel stainless steels.

• **Montana Section** and the Last Chance Gulch Mining Assn. held a joint meeting in the Montana Club in Helena, Mont. Fifty members and guests of the two groups were present. Clark Pyser, vice president of the Montana Society of Certified Public Accountants spoke on *Accounting and the 1954 Income Tax*. He stressed the effects of the new law on mining and petroleum men and the tax benefit sections pertaining to mineral deposits. The American Smelting & Refining Co., East Helena Div., sponsored the cocktail party.

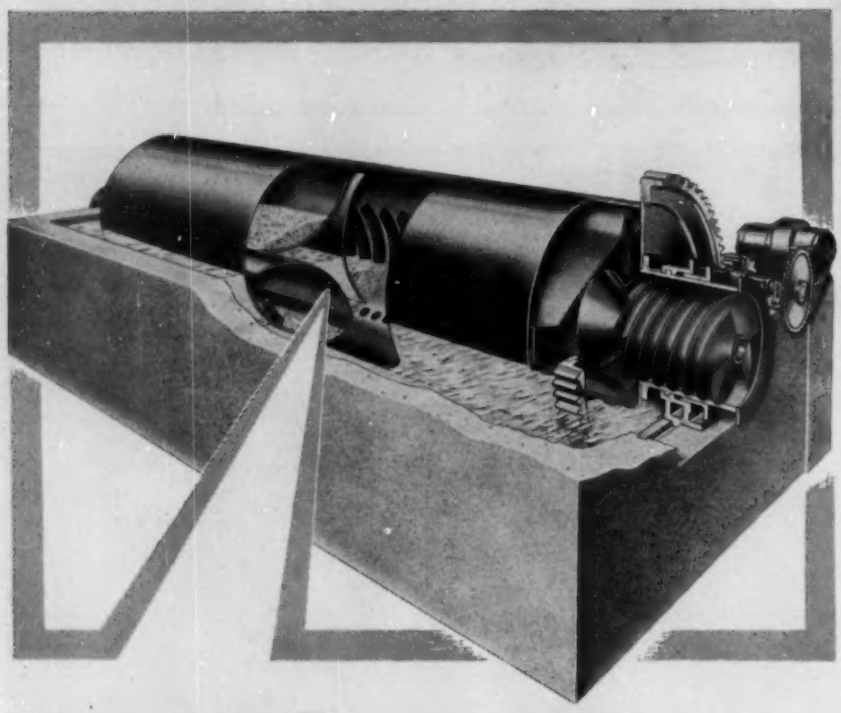
Joseph Roy, left, President of the Montana Section, welcomes AIME President-elect H. DeWitt Smith at the section's recent banquet at the Silver Bow Room, Finlen Hotel, Butte. The next day Mr. Smith addressed the entire student body at the Montana School of Mines.

• **The Tri-State Section** held a joint dinner meeting with the Missouri Society of Professional Engineers at Joplin, Mo. Following dinner and brief talks by officers of both organizations, Bruce Williams invited those present to view the Bruce Williams Laboratories Inc. Staff members conducted demonstrations of modern equipment and the functions they performed in the analysis of samples from all over the U. S. and several foreign countries. Before the meeting started, John Inman, Vice Chairman of the Section called a special meeting of the six remaining Directors. Mr. Inman was named Chairman of the **Tri-State Section,** replacing Ken Nobs who resigned recently because of his departure from the area. Ward Ball, Baxter Springs, Kan., was named to replace Mr. Nob's directorship. George Komadina was appointed a director to replace Ed Crabtree. Mr. Komadina was also named delegate to the Section Delegates Meeting at Chicago in 1955. Clinton C. Knox will go as alternate delegate in place of J. C. Stipe should an alternate be needed.

• Annual joint meeting of the **University of California** and **Stanford University Student Chapters** with the **San Francisco Section** was held November 10 at the University of California. Host student chapter was the University of California Mineral Technology Assn. in Berkeley. Dean M. P. O'Brien, College of Engineering, UC, spoke on *Modern Educational Trends in Engineering.* **San Francisco Section** Prize Awards were presented to Stuart F. Frederick and Jack Washburn, students at UC last year.

• Members of the **Philadelphia Section** recently took part in a field trip to the Fairless Steel Works. Later, 27 of the 53 persons who attended had lunch at the Pennsbury Inn.

• Some 20 members of the **Southern Sierra Subsection** attended the meeting at the Sierra Cafe in Lone Pine, Calif. Most of the program was given over to a color movie on Alaska gold mining furnished by the U. S. Smelting Refining & Mining Co. Coincidentally, the meeting was held on the 87th anniversary of the Alaska purchase. Film narration was by Dan Jones who was born and raised in the Territory.



GET THE *Inside Story*

—ON FASTER COOLING, MINIMUM FLOOR SPACE AND DRIVE POWER

The **STEARNS-ROGER IMPROVED CALCINE COOLER** uses internal cells which approximately double the cooling surface—taking full advantage of the economy of water cooling both by conduction and evaporation.

Pre-determined cooling. Special flights or lifters on the slowly revolving cylinder advance the hot material thru the proper length of Cooler to obtain the desired temperature.

Low power requirements. Water level is regulated so Cooler and its load virtually float. Minimized weight, plus suitable trunnion bearings, reduce friction and power needs.

Protection of shell. Even in case of shut down with a hot load, shell is protected by its cooling water jacket.

Continuous feed. *Minimum dust loss. Can be sealed against contaminating atmosphere.*

WRITE FOR BULLETIN

Stearns-Roger

THE STEARNS-ROGER MFG. CO. DENVER, COLORADO

• The **Philadelphia Section** met on Nov. 18, 1954 and enjoyed a cocktail hour and dinner in which both the minerals and metallurgical members participated.

The speaker for the minerals group was A. B. Cummins, manager of the minerals, magnesia and basic research dept. of the Johns Manville Co. His topic was *Minerals Used by the Johns Manville Co.*

H. H. Ulig, of the Massachusetts Institute of Technology, gave an unusually fine talk on *Metallurgical Factors in Corrosion Reactions.*

• Alfonso Ballon has been elected a member of the Program Committee of the **Lima, Peru Section.** Bernard A. Bramson continues as chairman of the committee. The election report carried in September 1954 MINING ENGINEERING incorrectly listed Mr. Ballon as committee chairman.

• At a recent meeting of the **New York Section** R. H. Channing was awarded the Legion of Honor in absentia by E. O. Kirkendall, Administrative Assistant Secretary, AIME. Mr. Channing is president of Hudson Bay Mining & Smelting Co. Howard Meyerhoff, executive director of the Scientific Manpower Commission spoke on *What Can Be Done to Interest Students in Mining and Metallurgy?* His talk evoked an extremely animated discussion from the floor.

• What amounts to one of the best explanations, simple, clear, concise, of the comprehensive principles of atomic energy are presented in the 16mm sound motion picture in full color animation, *A is for Atom.* The film tells you what an atom is, how atoms are split, how isotope families make up the 92 elements in nature, how a reactor pile works, and how atomic energy can be applied to a peacetime world. The film can be borrowed from General Electric film libraries in Atlanta, Baltimore, Boston, Chicago, Cleveland, Dallas, Denver, Detroit, Los Angeles, New York City, Philadelphia, Pittsburgh, St. Louis, Salt Lake City, San Francisco, Seattle, Syracuse, and Washington, D. C.

• *Design for Excavating,* a 16 mm color motion picture, issued by the Hyster Co. shows the advantages of the ½-yd excavator-crane mounted on a heavy duty crawler tractor. The film was made at actual job sites and shows the convertibility of the machine to a shovel, backhoe, dragline, clamshell, crane, pile driver, and bulldozer. Caterpillar-Hyster dealers should be contacted for arrangements to see the film. The Hyster Co. may also be contacted at 2902 NE Clackamas St., Portland 8, Ore.

• Marion Power Shovel Co. has two 16 mm color-sound films featuring material handling excavators in action. The *Marion 191-M* tells the story of the world's largest shovel on two crawlers and *Marion and You* features the company's entire line. The firm's advertising dept., Marion, Ohio, handles the movies.

Personals

C. L. SOLLENBERGER

W. M. Kelley has been elected president of Reserve Mining Co., jointly owned by Republic Mining Co. and Armco Steel Corp. Mr. Kelley, who was vice president in charge of operations, Republic Mining Co., still will be available to Republic in a consulting capacity, but his first responsibility will be to Reserve which has a $160 million taconite project in Minnesota. He will maintain offices in Silver Bay, Minn., and Cleveland.

Hamilton M. Ross, manager of Hewitt-Robins' plants in Passaic, N. J., and Philadelphia, has been appointed manager of operations of the conveyor div. and **Harold E. Murken** has been appointed manager of conveyor system sales. Mr. Ross joined Hewitt-Robins in 1941 as a design and layout engineer and Mr. Murken joined the company in 1927 as an accounting clerk.

Samuel S. Douglas, Joy Mfg. Co., Pittsburgh, has been made a special representative to the iron and steel industry. Mr. Douglas has been a member of the Joy organization as a representative in the Pittsburgh district since 1948. Prior to that he was vice president of engineering and sales, Arms Franklin Corp., Franklin, Pa.

Lawrence E. MacDonald has been appointed general sales manager for Bucyrus-Erie Co., South Milwaukee, Wis. Mr. MacDonald, who will take over responsibility for all domestic sales, has been with Bucyrus-Erie for more than 28 years. Since 1949 he has been sales manager, excavator distributors.

Robert Connett, who was with Canadian Gypsum Co., Windsor, Nova Scotia, is now with Jamaica Gypsum Ltd., Jamaica.

Gerald A. Munson of the Lithium Corp. of America Inc., Minneapolis, has been made general manager of the North Carolina plant in Bessemer City, now under construction.

C. L. Sollenberger has been appointed supervisor of process engineering section and **T. G. Kirkland** has been appointed engineer in charge of the process laboratory, according to a recent announcement by **H. K. Ihrig,** vice president in charge of research for Allis-Chalmers Mfg. Co. Mr. Sollenberger received his M.S. from MIT in 1948 and Mr. Kirkland received his B.S. from Montana School of Mines in 1947. Both men joined Allis-Chalmers in 1948 and both have contributed articles to technical publications.

Thomas F. Edson, assistant vice president of research and development, American Potash & Chemical Corp., Los Angeles, has been promoted to a newly created position of vice president in charge of special engineering projects. He will be in charge of construction and initial production at the new $6 million American Lithium Chemicals Inc. manufacturing plant near San Antonio, Texas. Mr. Edson has been responsible for the selection of the site and the engineering on the plant.

Clinton N. Hernandez, Turner Construction Co., New York, has been elected a vice president. Mr. Hernandez joined this company in 1942. From 1943 to 1948 he was resident project manager for Turner's operations at Oak Ridge, Tenn., and from 1948 to 1951 he was in general supervision of that project. Mr. Hernandez, who will continue to be in charge of special projects, was the executive in charge of Turner's construction work for White Pine Copper Co., White Pine, Mich., Bethlehem Mines Corp., Marmora, Ont., and titanium facilities for Cramet Inc. at Chattanooga, Tenn.

Arthur W. Fasold has been named assistant to the general sales manager of the conveyor and rubber divisions, Hewitt-Robins Inc., Stamford, Conn. Mr. Fasold has been with this company since 1947.

Robert D. Nininger of Arlington, W. Va., deputy assistant director for exploration, AEC, is the author of *Minerals for Atomic Energy,* recently published by Van Nostrand. (*See Books, December 1954.*)

Ross M. Durland has been appointed assistant plant chemist, Calveras Cement Co., San Francisco. Mr. Durland was plant superintendent, Southwest Potash Corp., Carlsbad, N. M., and before that superintendent of the Crystallizer Div., American Potash & Chemical Corp., Trona, Calif.

Emanuel Herzog, consulting hydrogeologist on the staff of World Mining Consultants Inc., is in Turkey heading a mission financed by the FOA to assist the Turkish Government to develop ground water supplies in the arid valleys of southeast Turkey.

T. G. KIRKLAND

William W. Tamplin arrived recently in Djakarta, Indonesia. He is scheduled to remain there with the J. G. White Engineering Corp., which serves the Indonesian Government as consultants, until the end of 1955. Mr. Tamplin will be concerned principally with the exploration and development of mineral resources.

Richard H. Swallow has been elected a vice president of Ayrshire Collieries Corp., Indianapolis. Mr. Swallow has been with Ayrshire and its predecessor companies since 1937. He has been chief engineer since 1940, serving continuously in that position except for a leave of absence when he was with the U. S. Coal Mission to Great Britain to assist in the development of open-cast mining in England.

John J. Curzon has resigned as deputy director of the Mining Div., AEC, Grand Junction, Colo, to become new director of the exploration and development dept., Climax Molybdenum Co. This department will establish temporary offices in the Midland Savings Bldg. in Denver.

Conrad R. Appledorn is a geologist with the Engineering Geology Branch, U. S. Geological Survey, Menlo Park, Calif.

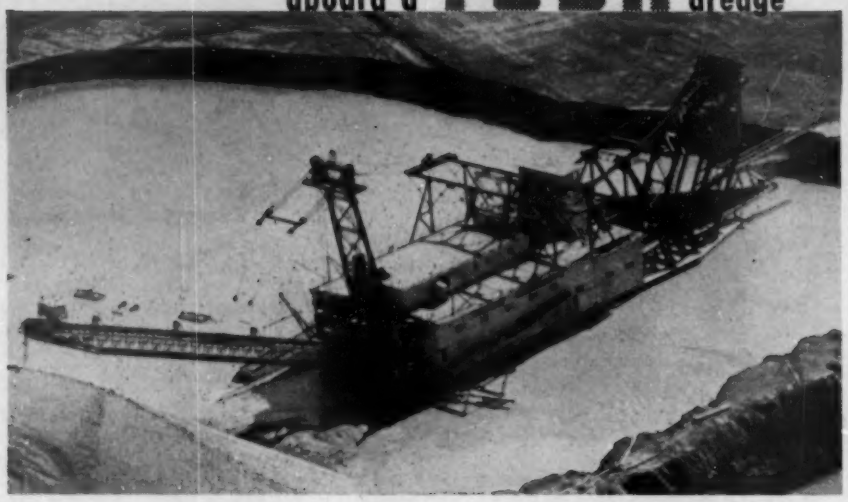
Harry J. Wolf examined uranium and tungsten properties in California and uranium and copper properties in Arizona during October and November.

Elis Dahlström has left his position with Boliden Mining Co., Falun, Sweden, and is now consulting geologist for Hans Lundberg and Lundberg Explorations Ltd. of Toronto. His office is in Stockholm.

Dudley L. Davis has been named assistant chief of the Salt Lake Exploration Branch of the AEC, Salt Lake City. He was formerly with the Darwin and Shoshone Mines Div., Anaconda Copper Mining Co., Darwin, Calif.

To producers of sand and gravel, rare earths, and other mineral products

Combine digging and made-to-order processing plant aboard a YUBA dredge



This Yuba dredge (4000-ton displacement) digs 112 ft. below water with 18 cu. ft. buckets; has ample deck space for processing machinery.

Dredging costs under 5¢ per ton for gravel are not uncommon with large YUBA bucket ladder dredges. They also have dug cemented gravel, boulders, and into bedrock without costly drilling and blasting. They float in their own ponds, excavate without lowering surrounding water levels. Bucket sizes range from 2½ to 18 cu. ft. . . . digging depths from 10 ft. or less to 125 ft. below water.

Complete Plant Afloat

Your YUBA dredge can be built to screen out rocks; to break up and wash away surplus clay; to size through single or multiple screens; to remove mineral products by jigs, cones or magnetic separators. In short, you can completely process and grade your product as you dig, all aboard a YUBA dredge.

Choice of Handling Methods

Your dredge can be designed to stockpile ashore, load into trucks or shore conveyor; load into barges; or pump ashore through pipes.

Consult YUBA NOW. We can build you a new dredge . . . redesign, move and rebuild a used dredge . . . to fit your particular needs. Wire, write or call us — no obligation of course.

67

YUBA DREDGES — PROVED DEPENDABILITY

YUBA MANUFACTURING CO.

Room 708, 351 California St., San Francisco 4, California, U. S. A.

AGENTS { SIME, DARBY & CO., LTD. · SINGAPORE, KUALA LUMPUR, PENANG.
SHAW DARBY & CO., LTD., 14 & 19 LEADENHALL ST., LONDON, E. C. 3.

CABLES: YUBAMAN, SAN FRANCISCO · SHAWDARBCO, LONDON

James H. Wren, general manager of J. H. Wren & Co., consulting mining engineers, is directing the production engineering and management policies at the following producing mining projects: Butler Mining & Development Corp.'s Sugar Loaf gold mine near Shingle Springs, Calif., Buckhorn Tungsten Mining Co.'s Dinky Creek, Calif., operation, Goodhope Tungsten Mining Co.'s Three Rivers, Calif, mining and milling enterprise, Sonny Boy mine of the Nev-Tah Oil & Mining Co. near Bishop, Calif., and the Mary silver and lead mine, Douglas County, Nev.

Frank W. Millsaps, formerly assistant mill superintendent, National Lead Co., Baxter Springs, Kan., is now metallurgist with Idarado Mining Co., Ouray, Colo.

Andrew Allan, Jr., has resigned from Manu-Mine Research & Development Co., Reading, Pa., to accept a position with Thompson Creek Coal & Coke Corp., Denver.

C. A. Botsford, after a summer at home in the U. S., has resumed his position as mining engineer at the London Field Office of General Services Administration. Mr. Botsford has worked as a consultant on the U. S. Government mineral program in Europe and Africa since 1950.

Jules R. Timmons, president, Hollinger-Hanna Ltd., Montreal, has announced the appointment of **W. H. Durrell** as vice president and **C. E. McManus** as general manager. Mr. Durrell was formerly general manager of Hollinger-Hanna and Mr. McManus was formerly project manager of Iron Ore Co. of Canada. Hollinger-Hanna Ltd. is the company appointed by the Iron Ore Co. of Canada as its agent for the management of its operations.

Alfred Petrick, Jr., is project engineer, Exploration Div., Engineering Branch, AEC, Grand Junction, Colo.

Arnold H. Kackman is with Cia. Minera de Nariño, Pasto, Colombia. He is junior engineer on the Barbacoas operation.

Samuel M. Hochberger, formerly special sales representative, Atlas Powder Co., Wilmington, Del., is vice president, Maurer & Scott Inc., Philadelphia.

C. G. Palmer has resigned as manager, Eldorado Tennant Creek Ltd., Tennant Creek, N.T., Australia, to join the staff of Mount Isa Mines Ltd., Queensland, Australia.

D. B. Sikka is a geologist with Algoma Ore Properties Ltd., Jamestown, Ont.

Geoffrey A. Cox, who was with Boliden Gruv A/B, Laisvalls, Gruva, Sweden, is now with Cassiar Asbestos Corp. Ltd., Cassiar, B. C.

Jack Kratchman, party chief, **Arthur Richards** and **Gerald Gershten,** geologists, have been assigned by the Exploration Div., AEC, to an eastern U.S. reconnaissance program. They will evaluate uranium possibilities in the eastern states by a program of airborne scintillation counter surveys, general reconnaissance, and assistance to the public interested in prospecting for uranium in the East. Their headquarters will be 70 Columbus Ave., New York.

James D. Mulryan, quality assistant, U. S. Gypsum Co., Ft. Dodge, Iowa, leaves in March for two years in the Corps of Engineers as second lieutenant. Mr. Mulryan was graduated from Colorado School of Mines in 1954.

Philip F. Beaudin, senior vice president of Copper Range Co., Boston, and a former director, resigned as a vice president, Dec. 31, 1954, after 50 years of service in the mining industry. Mr. Beaudin had been associated with Copper Range and affiliated interests in an executive capacity since 1930. Previous to his transfer to Boston, he was vice president and general manager of East Butte Copper Mining Co. and affiliated interests in Montana, Colorado, Nevada, and Wyoming, with executive offices in Boston and general offices in Butte, Mont., where he resided for 25 years. Mr. Beaudin, a member of several civic and social organizations, was formerly chairman of the Mines Committee of the Northwest Advisory Board.

Roger Howell recently returned to the U. S. from Rangoon, Burma, where he completed an 18-month assignment for Pierce Management Inc., mining engineers and mine managers, Scranton, Pa. Mr. Howell was manager of an exploration and drilling project on the coal deposits in the Upper Chindwin District.

Allen A. McKinney, who was with the U. S. Bureau of Mines, Knoxville, Tenn., is now with Rare Metals Corp. of America, Salt Lake City.

H. I. Altshuler, consulting mining engineer, is in Brazil for a year-end inspection of the operations of the St. John d'el Rey Mining Co. Ltd.

G. V. Woody, manager of Allis-Chalmers Mfg. Co., processing machinery dept. since 1945, has been appointed special assistant to **C. W. Schweers,** vice president, director of sales, general machinery div. Mr. Woody, who has been with Allis-Chalmers since 1909, will be succeeded by **William M. Wallace.** Mr. Wallace, who has held several positions with Allis-Chalmers including assistant to the vice president of A-C general machinery div., received a master's degree in 1951 in business and engineering administration from MIT following a year of study under a Sloan Fellowship.

A. G. GILBERT

A. G. Gilbert has been appointed manager, standard product sales, Heyl & Patterson Inc., Pittsburgh. In his new position, Mr. Gilbert will have charge of the sales of the standard products sold by Heyl & Patterson to the coal, utility, mining, steel, and chemical industries. Prior to joining this company in 1947 as contracting engineer, he was sales engineer for Harris Pump & Supply Co., Pittsburgh.

F. S. Barnard, has resigned his position as project engineer, Southwestern Engineering Co. of Los Angeles, to join Petaca Mining Corp., Santa Fe, N. M., as superintendent, building and operating a new ground mica plant. It is hoped that the plant will be in operation early this year.

L. R. Messer, consulting engineer of Van Nuys, Calif., who recently erected and started two Pacific furnaces at Almaden, Spain, has been examining mercury prospects and mines for San Francisco clients.

Bart Cox, who was with Broulan Reef Mines Ltd., Pamour, Ont., is now with Paymaster Consolidated Ltd., South Porcupine, Ont.

Robert M. von Storch has been appointed superintendent of coal mines and quarries, Columbia-Geneva Steel Div., U. S. Steel Corp., Dragerton, Utah. Mr. von Storch succeeds **Frank V. Hicks** who retired in November. Also at Columbia-Geneva, **James Cassano,** formerly supervisor of industrial relations, mines and quarries, has been appointed superintendent of the division's Columbia coal mine near Dragerton.

James H. Pierce, chairman, Pierce Management Inc., Scranton, Pa., **John Marshall,** president, and **F. L. Rousselle,** executive vice president and treasurer, have organized the Coaldale Mining Co. Inc. to operate the Coaldale mine. This mine produces 6000 tpd of anthracite coal and employs 1500 men. Mr. Pierce is president of the new company, Mr. Marshall, executive vice president, and Mr. Rousselle, vice president and treasurer.

H. DeWitt Smith, a director of Newmont Mining Corp., New York, and President-Elect AIME, was a speaker at the recent annual western meeting of the Canadian Institute of Mining and Metallurgy in Vancouver.

James L. Head led the industry's participation in the Arthritis & Rheumatism Foundation's 17-hr telethon broadcast December 11 over WABC-TV channel 7. He appeared on the show at the Mining phone and took contribution pledges from friends and associates in the industry. Mr. Head, mining engineer, Anaconda Copper Mining Co., New York, was also recently re-elected president of United Engineering Trustees Inc.

Werner P. Wolff, chief mining engineer, Hibbing-Chisholm district, Oliver Iron Mining Div., retired from active service with the company, Nov. 1, 1954. He had been associated with the Lake Superior iron mining industry since his graduation from the University of Wisconsin in 1912. Succeeding Mr. Wolff as chief mining engineer is **Milton R. Sermon.** Before joining Oliver in 1942, Mr. Sermon was with Pickands, Mather & Co. in Minnesota and Phelps Dodge in Arizona. He was also employed as a construction engineer by the Special Engineering Dept. of the Panama Canal.

A. J. O'Connor, general manager and vice president, was recently presented with a watch and honored at a testimonial dinner by Consolidated Coppermines Corp., Kimberly, Nev. He was one of seven men who have 25 years employment with the firm.

Robert B. Schlosser, mining engineer, formerly with Anaconda Copper Mining Co.'s fertilizer dept. in charge of open pit work, is now working with Anaconda's New Mexico operations in Grants.

Sheldon P. Wimpfen, manager of the Grand Junction, Colo., operations office, AEC, was honored in November as "the outstanding ex-student for 1954" of Texas Western College of the University of Texas in ceremonies in El Paso. Mr. Wimpfen, a 1934 graduate, gave a short address on *Raw Materials for Atomic Energy.*

Edwin Letts Oliver, president Oliver United Filters Inc., San Francisco, and AIME Director, represented the Institute at the dedication in October of the new campus at San Francisco State College.

Harry E. Puttuck, geologist, Phoenix, Ariz., who was with the AEC, is now with Continental Uranium Co.

William J. Waylett, formerly special assistant to director, Div. of Raw Materials, AEC, Washington, D. C., has been made chief, Technical Services Branch.

John W. Finklang, who has been in the Army, has returned to Anaconda Copper Mining Co., Butte, Mont., as an assistant mining engineer at the Emma mine.

Marjorie Prescott is now employed by the AEC, Washington, D. C. Miss Prescott is a 1954 graduate of the University of New Hampshire, Durham.

Berl A. Trafton is assistant mine engineer, U. S. Gypsum Co., Midland, Calif.

Frank A. Ayer, consulting engineer, New York, recently returned from a 2600 mile trip. Mr. Ayer visited the Island of Cyprus, copper mines in Northern Rhodesia, and gold mines on the Rand in Africa.

Stuart A. Falconer was named chief metallurgist of the Mineral Dressing Dept., American Cyanamid Co., New York, to fill the vacancy caused by the recent death of **S. J. Swainson.** A 1924 graduate of the University of British Columbia, Mr. Falconer has been with American Cyanamid since 1927. He has written many technical articles.

R. P. Charbonnier, who was with Big Horn & Saunders Creek Collieries Ltd., Saunders, Alberta, is now with the Fuels Research Laboratory, Dept. of Mines & Technical Surveys, Calgary, Alberta.

J. G. HUSEBY

J. G. Huseby, assistant general manager, Mountain Copper Co. Ltd., San Francisco, since 1946, has resigned. He will devote his future service to consulting work in mining and metallurgy with offices at 777 Euclid Ave., Berkeley, Calif. After graduating from Oregon State College in 1930, Mr. Huseby joined Mountain Copper as an engineer. He later served as quarry foreman, cyanide plant superintendent, general superintendent, and directed and evaluated research involving chloridizing roast of calcines, followed by acid leaching for copper and zinc, producing cupric copper, zinc oxide, and sintered iron ore.

Paul I. Birchard has been appointed vice president and general manager, Westinghouse Air Brake Co.'s Le Roi Div., Milwaukee. Mr. Birchard replaces **Edward J. Green,** who has been temporary general manager of the Le Roi Div. since the resignation of **T. O. Liebscher,** former president of the Le Roi Co. Mr. Green will return to Westinghouse Air Brake headquarters in Pittsburgh to resume his position as executive to the president. For the last six years, Mr. Birchard, who has some 26 years experience in the diesel engine industry, has been vice president and general manager, Enterprise Engine & Machine Co., San Francisco.

Robert P. Brooks has been appointed northwestern sales manager for Bucyrus-Erie Co. and will maintain headquarters in the Seattle district sales office. Mr. Brooks takes over responsibility for the sales of all Bucyrus-Erie products in Washington, Oregon, Idaho, Montana, Alaska, British Columbia, Alberta, and the Yukon Territory.

Charles Weiler, Alan Wood Steel Co., Dover, N. J., has been promoted from mine captain to assistant superintendent, Scrub Oak iron mine.

Herbert G. Dillon, formerly vice president in charge of sales, Heyl & Patterson Inc., Pittsburgh, has been appointed sales manager, Mead-Morrison Div., McKiernan-Terry Corp. of Harrison and Dover, N. Y. Mr. Dillon will have charge of the company's sales of coal and ore unloaders, car hauls, dumpers, and other materials handling equipment.

J. M. Rose, who was with Zinc Corp., Broken Hill, N. S. W., Australia, is now in Canada where he is working for International Nickel Co., Sudbury. Ont.

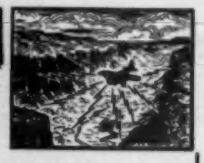
A. K. Snelgrove, who has been lecturing at the University of Hong Kong on a Fulbright award, has returned to Houghton, Mich., where he is head of the dept. of geological engineering, Michigan College of Mining & Technology. Mr. Snelgrove has arranged a series of illustrated lectures on his experiences.

John R. Reynolds, formerly with the consulting partnership of Preston & Reynolds, Kellogg, Idaho, has accepted a position as mining geologist with Rare Metals Corp. of America, Boise, Idaho. This is a newly formed subsidiary of the El Paso Natural Gas Co.

S. Siscoe is with Campbell Red Lake Mines Ltd., Balmerton, Ont. He was with Mindamar Metals Corp., Sterling Richmond Co., Nova Scotia.

Eugene R. Palowitch is assistant professor, School of Mines, West Virginia University, Morgantown.

TURN ON THE HEAT!



Airborne or underground — new BISMUTH NUCLIOMETER can take it! No heat-sensitive crystals and photomultipliers to fail when temperature soars — minor repairs in the field are a cinch!

Instant "zero" set; time response from 2 to 16 seconds. For airborne and jeep work — *full scale sensitivity is 0.005 MR/HR!* 10½ pound weight includes case, remote control meter, 10 feet cable. *Complete $1295* in U. S. and Canada.

World-wide professional service; photogeology, ore-finding and precise airborne radiometric campaigns, mine evaluation and management, prospect to concession. Use our quarter-century experience.

STRATEX INSTRUMENT CO., INC. EXPLORATION COMPANY | 3515A Sunset Boulevard Los Angeles 27, Cal., U.S.A.

Write for free literature on this and other rugged nucliometers, scintillatrons, scalers and Geigers.

"Cape Ann"

Forged Steel Drop Ball

FOR ECONOMICAL SECONDARY BREAKAGE

Prices and information on request
Available 2000 to 12000 lbs.

CAPE ANN ANCHOR & FORGE CO.
P.O. BOX 360M, Gloucester, Mass.

A. H. Jones, formerly vice president in charge of the Export Div., Gardner-Denver Co., New York, has been named vice president and director of export sales for the company. Succeeding **Norman Nevin** as district manager of Gardner-Denver's branch office, Lima, Peru, is **John J. Mastrovich.** Mr. Nevin is now manager of the export office in New York.

William Bellano has been appointed production manager of the Phosphate Chemicals Div., International Minerals & Chemicals Corp. He will be in charge of International's new phosphate chemicals plant at Bonnie, Fla., and also will be responsible for the corporation's phosphate chemicals operations at Tupelo, Miss., and Wales, Tenn. Mr. Bellano was formerly manager of general engineering of the corporation's Engineering Div.

Charles R. Knopp, mining engineer, is with U. S. Gypsum Co., Sweetwater, Texas.

Glen D. Chambers is now branch manager, Yukon Equipment Inc., Anchorage, Alaska. Mr. Chambers received his M.E. from the University of Nebraska in 1942 and following service in the Army as a lieutenant in the Ordnance Dept., joined Yukon Equipment in 1946.

John S. McNabb, Jr., has resigned as resident mining engineer, U. S. Bureau of Mines, Butte, Mont., to accept a position as mining engineer on the staff of International Minerals & Chemical Corp., Chicago.

John F. Colman, formerly chief engineer, Washington Steel & Welding Co., Tacoma, Wash., is now chief engineer, Pointer-Williamette Co., Edmonds, Wash.

A. S. Walter, who has been making appraisals on mining properties since 1943 for the War Dept. and Justice Dept. in the West was an expert witness in the federal court in Billings, Mont., for the Government in the Mouat Chrome-Nickel case the latter part of October. Mr. Walter was formerly dean of mining and metallurgy, New Mexico School of Mines, and has been actively engaged in consulting work since he left that institution in 1944.

John Lasio is assistant mining manager, Calumet & Hecla Inc., Calumet Div., Calumet, Mich.

J. C. Landenberger, Jr., has been appointed general superintendent of operations, Utah Copper Div., Kennecott Copper Corp., Salt Lake City. Also at Kennecott, **V. S. Barlow** has been made general superintendent of mines, **Ernest C. Simkins,** mine superintendent, **Joseph A. Norden, Jr.,** assistant mine superintendent, and **Duane O. Olsen,** director of labor relations.

ROBERT K. McKECHNIE

Robert K. McKechnie has been named the new unit manager of a materials application unit, established in the metallurgy dept., General Electric Research Laboratory, Schenectady, N. Y. Mr. McKechnie has been with GE since 1947, serving at Knolls atomic power laboratory and with the Carboloy dept. before becoming a research associate in the materials and processes section of the GE laboratory in 1952.

A. E. Jones, chief engineer, mining dept., Cerro de Pasco Corp., Casapalca, has completed his contract with this firm and has returned to England.

George H. Kemmer, formerly chief geologist, chief mining engineer, for the Ministry of Finance, Dept. of Mines, Imperial Ethiopian Government, Addis Ababa, returned from Ethiopia last August, having spent five years there. Since then, Mr. Kemmer has been carrying out heavy mineral investigations in Northern Mexico and the Southwest with **Alexander T. Roberts.** Mr. Roberts, a placer engineer from Scotland, was recently engaged in placer development along the Southeast Sudan Border.

Gerald M. Friedman has resigned as assistant professor of geology, University of Cincinnati, to be a consulting geologist with Harico Mining & Development Co. and Talvey Metal Mines, Sault Ste. Marie, Ont.

Verne D. Johnston, mining engineer with Oglebay, Norton & Co., Cleveland, has retired, but will be retained in a consulting capacity. Mr. Johnston has taken an active part in the taconite development in Minnesota and was a member of the original group that started the Mining Symposium, sponsored by the Center for Continuation Study of the University of Minnesota. He was graduated from Michigan College of Mines in 1913 and after working as assistant engineer with Montreal Mining Co., Hurley, Wis., became mining engineer and geologist in 1918 with E. W. Hopkins, range manager for Oglebay, Norton & Co.

SEND FOR 248-PAGE
WILMOT CHAIN & CONVEYOR Catalog
W
WILMOT
As Originators of Rivetless Chain, Wilmot Offers Widest Choice of Chain Sizes and Conveyor Attachments
Catalog 513 is a standard reference on rivetless chain for all applications. Lists the largest available choice of chain sizes and attachments; also every type of part for conveyors and elevators.
Investigate Wilmot DUCTILE IRON Castings - Bulletin 512
Chains
CONVEYORS · ELEVATORS
WILMOT ENGINEERING CO.
HAZLETON, PA.
Foundry and Shops: WHITE HAVEN, PA.

Obituaries

Malcolm Black

An Appreciation by
R. L. Healy

Malcolm Black, mill superintendent of Wright-Hargreaves Mines Ltd., died suddenly at his home in Kirkland Lake, Ont., on Nov. 7, 1954 at the age of 69 years.

He was born in Carluke, Scotland, on Apr. 26, 1885 and was educated in the technical schools of that country.

He came to Cobalt about 1906 and prospected in Cobalt and Larder Lake areas of northeastern Ontario and in northern Manitoba.

Early work in mines and mines of Cobalt was followed by metallurgical and milling experience at the old Vipond mine in Porcupine and at the Hollinger mill in Timmins for about eight years. During World War I he was at the Moose Mountain Iron mine. He was in charge of milling at the Argonaut mine east of Kirkland Lake between 1923 and 1926 which was followed by two years with the Associated Goldfields mill near Larder Lake. He joined Wright-Hargreaves Mines Ltd. in August 1928 of which milling plant he was in charge until the time of his death. It was between 1932 and 1933 that the mill capacity was doubled to 1250 tpd.

Mr. Black had an ever-inquisitive mind toward improving the metallurgy and efficiency of his cyanide milling plant and was recognized by his fellow metallurgists and millmen in the gold mining camps of Canada and the U. S. as a keen student of his work. In that regard, he contributed of his experience in the following papers:

Sampling Methods at the Mill of Wright-Hargreaves Mines, Trans., CIM, Vol. 38, 1935. *Milling and Metallurgy at the Wright-Hargreaves Mines, Limited*, Trans., CIM, Vol. 38, 1935. *Wright-Hargreaves Improves its Milling Practice*, Engineering & Mining Journal, March, April, and May, 1939. *Recent Improvements in Milling Practice at Wright-Hargreaves*, Trans., CIM, Vol. LI, 1948.

He was a member of the Canadian Institute of Mining and Metallurgy, the AIME (1940), and the Assn. of Professional Engineers of Ontario.

He was constructively interested in people and was especially active among boys. His work with the camera was well recognized, many of his pictures having been shown in the salons of Canada and the U. S. His adeptness with the movie camera has been recorded in the filming of the mining, milling, and surface operations of the Wright-Hargreaves mine and more recently in his colored films of holidays spent in the Maritime Provinces and in Scotland and England.

Mr. Black was a member of the United Church. He was a member of the Masonic lodge in Kirkland Lake which order he joined in 1907; he was also a charter and life member of the Timmins lodge.

He is survived by his wife, the former Ascelia Baxter of Cobalt, and by two sons and one daughter, Andrew a metallurgical engineer of Cobalt, Keith of Ottawa, and Margaret (Mrs. G. M. Douglas) of Chatham, Ont.

Alex McDonald

An Appreciation by
Vincent D. Perry

With deep sorrow we record the death of Alex M. McDonald (Member 1921), Oct. 27, 1954 after a brief illness in Salt Lake City.

Alex was born Aug. 24, 1901 in Butte, Mont. His boyhood years were spent in Butte as well as in construction camps in western Montana and British Columbia where his father was engaged as an independent contractor during the building of the Milwaukee and Canadian Pacific railroads across the mountains to the west coast. It was natural, then, that Alex' early contacts with mining and construction led him to the Montana School of Mines in Butte where he graduated with the class of 1922.

His first job after graduation involved mine and geological model building for Anaconda in connection with litigation over certain Butte veins. The well-earned, successful outcome of the litigation and the experience gained in applying detailed, precise methods on scale models to problems of complex structural geology sharpened in Alex an appreciation of applied geology that became the foundation on which he built his subsequent varied and successful professional career.

In November 1927, Alex married Florence Greenfield of Butte and to them were born a daughter, Joan, and a son, Alex C. McDonald.

During the late years of the twenties and into the economic depression of the thirties, Alex worked as a mining geologist for Anaconda and for the North Butte Mining Co. Also participating energetically in public affairs, he was in charge of WPA relief for the Butte community, and as Secretary-Treasurer of the Montana Section of the AIME, he was leader for many years in the regional activities of the Institute.

In 1935, with gold mining in the ascendency, Anaconda undertook the reopening of the Mayflower gold mine near Whitehall, Mont., and Alex was placed in charge of the operation. The high ratio of net profit to relatively small output of medium grade ore that resulted from his management, provided a striking testimonial to the successful integration of ore finding ability and operating skill. The remarkable dividend record of the Mayflower mine in those years can be attributed in large measure to Alex McDonald.

In 1942 Anaconda initiated exploration of the Yerington porphyry copper in western Nevada. Alex was called upon to supervise this work. When early drilling results, because of bad ground, were not conclusive, he undertook the difficult task of sinking an exploration shaft against a heavy head of water and opening the orebody with underground workings. The success of this latter phase of exploration, achieved under the most difficult operating conditions of water flow and heavy ground, led eventually to development of the Yerington mine as one of the large open pit porphyry copper producers of the U. S.

During recent years, Alex served ably and energetically as assistant chief geologist of Anaconda in charge of outside exploration in the U. S. and Canada. His many friends and business acquaintances in the two countries are living proof of the fine personal attributes which drew so many people close to him.

Loyalty and honesty were his two prime qualities and these he rated over an infinite variety of technical

Necrology

Date Elected	Name	Date of Death
1914	Raymond F. Bacon	Oct. 14, 1954
1919	Ernest C. Bierce	July 9, 1954
1940	Malcolm Black	Nov. 7, 1954
1945	Charles M. Brown	Aug. 10, 1954
1917	J. J. Carrigan	Unknown
1921	V. A. Gilles	Nov. 9, 1954
1919	Horace R. Graham	Nov. 8, 1954
1905	George A. Guess	Oct. 21, 1954
1908	William Gummere	June 5, 1954
1914	Thomas R. Jones	Apr. 19, 1954
1921	Mack C. Lake	Nov. 9, 1954
1902	J. B. Landfield	Nov. 22, 1954
1953	Hanney Macari	Apr. 2, 1954
1942	J. B. Martin	May 19, 1954
1941	Walter L. McCloy, Jr.	July 6, 1954
1921	Alex. M. McDonald	Oct. 27, 1954
1898	Francis J. Oakes, Jr.	Aug. 14, 1954
1942	John W. Owen	Oct. 26, 1954
1953	W. E. Richey	Apr. 6, 1954
1950	Florence Robertson	Nov. 13, 1954
1904	George A. Schroter	Nov. 15, 1954
1941	H. Webb Smith	Nov. 14, 1954
1935	Winston W. Spencer	Sept. 21, 1954
1938	Anders P. Svenningsen	Unknown
1939	William Trotter	Unknown
1950	Harold J. Walker	Aug. 7, 1954

skills in setting standards for himself and his associates. His fairness and unimpeachable honor in business and professional contacts supplied an outstanding measure of Alex' character, and the loyalty with which he served Anaconda in turn reflects to the honor and dignity of that company. In his death we have all lost a great and good friend who gave unsparingly of himself to do a job well and to help others.

John William Owen

An Appreciation by
Richard V. Wyman

On Oct. 26, 1954 John William Owen, a member of AIME (1942), died of polio in the Los Angeles General Hospital where he had been since August 6. Previous to his illness he was employed by U. S. Vanadium Co. as a metallurgist at Bishop, Calif. Mr. Owen spent three years in Peru where he was employed by Cerro de Pasco Corp. at Morococha, Mahr, and Cerro de Pasco.

He was born Aug. 23, 1923 at Sheridan, Wyo., and served with distinction in the Army Air Corps in Europe during World War II. He is survived by his wife Ruth and two sons, David and John.

William S. Pugh (Member 1938) of Pottsville, Pa., died Jan. 19, 1954. He was a consulting mining engineer and also a mining engineer for Schuylkull County. Mr. Pugh was in active practice for more than 60 years and served many companies as an expert mining engineer on valuation of coal properties. He was born in Pottsville in 1871 and from 1898 to 1902 studied with I.C.S., Scranton. When 19 years old he started work as a chainman for a mining company and was later employed as a mining engineer by Crystal Run Coal Co., Mt. Hope Coal Co., and Girard Mam Coal Co.

Walter F. Rittman (Member 1919) died Sept. 26, 1954. He was head of the engineering dept. of Carnegie Institute of Technology from 1921 to 1933 and a pioneer in the field of chemical engineering of petroleum.

Mr. Rittman, in recent years a consulting engineer in Pittsburgh, was born in Sandusky, Ohio, in 1883. A graduate of Swarthmore College, he received his Ph.D. from Columbia in 1914. He was with the U. S. Bureau of Mines from 1914 to 1921 and while he was with the Bureau won national notice in 1915 when the Government announced his invention of a new petroleum cracking process. This process not only raised the production of gasoline, but made toluol and benzol from petroleum for the first time. Mr. Rittman gave his patent for this process to the Government.

Later Mr. Rittman served as consulting engineer for the State of Pennsylvania and the U. S. Dept. of Agriculture. He was the author of numerous articles dealing with application of physical chemistry for industrial processes, especially those dealing with fuel, oil, and gas. He was past national president of the Society of Industrial Engineers, a Fellow of the American Academy for the Advancement of Science, and a trustee of Ohio University.

Winston W. Spencer

An Appreciation by
William A. O'Neill
and
Harold Strandberg

Winston W. Spencer (Member 1935), mining engineer and chief engineer for the Goodnews Bay Mining Co., was killed Sept. 21, 1954 in a freak accident at the company property near Platinum, Alaska. Spencer, or Spence as he was called by all his friends and associates, was born in Craig, Colo., Feb. 16, 1905.

Spence started working on this unique project—the only producer of placer platinum on the North American continent—before his graduation from the University of Alaska, where, as a senior mining student in 1933 to 1934, he was chosen to do the initial laboratory work on separation of the platinum grains from the sluice box black sands. As a result of this student project he was eventually to play an important role in the development and growth of the Goodnews Bay operation.

Spence was an outstanding student, a credit to his university and to his chosen profession. He was always cool, methodical, and precise in his actions and determinations, and his quiet unassuming attitude and studious qualities made him highly respected by all who knew him.

Except for two seasons spent with Gold Placers Inc., Woodchopper Creek Div., Alaska, on graduation, Spence's entire professional career was devoted to the Goodnews Bay organization. Maintaining a winter home in Seattle, those periods were largely utilized in traveling and visiting other mining operations, so that new developments and equipment—especially in the placer field—were always familiar to him. With platinum holding his professional interest throughout his career, he was considered an authority on the subject.

The modern, progressive, and successful operation and record of the Goodnews Bay Mining Co. in its remote locale may well be a tribute to the outstanding engineering qualities and ability of Spence. He can well rest in peace with a job well done.

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on Nov. 30, 1954 was 21,692; in addition 2011 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; R. B. Caples, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, Sidney Rolle, J. H. Scaff, John T. Sherman, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Alabama

Birmingham—Neason, James E. (M)

Core Drilling
by Contract

Exploration for coal and other mineral deposits. Foundation test boring and grout hole drilling for bridges, dams and all heavy structures. ***Core Drill Contractors for more than 60 years.***

JOY MANUFACTURING CO.
Contract Core Drill Division • MICHIGAN CITY INDIANA

Arizona
Patagonia—Pratt, Morton E., Jr. (R. C/S—A-M)
San Manuel—Wilbins, Richard G. (R. C/S—S-J)
Silver Bell—Edwards, Thomas R. (R. C/S—S-M)

Colorado
Denver—Frost, Hildreth, Jr. (M)
Denver—Martin, Victor R. (C/S—A-M)
Denver—Wilfley, Arthur R. (J)
Golden—Grosvenor, Niles E. (R. C/S—S-M)
Grand Junction—Donnerstag, Philip (R. C/S—A-M)
Grand Junction—Gardner, Conrad I. (R. C/S—S-M)
Grand Junction—Haldane, William E. (R. C/S—J-M)
Grand Junction—Holmes, Thomas W. (R. C/S—S-M)
Grand Junction—O'Rear, Neilsen B. (A)
Telluride—McCall, George T. (J)
Uravan—Blamey, Sanford E. (R. M)

Florida
Lakeland—Decker, Frank C. (J)

Illinois
Chicago—Good, John E. (M)
Chicago—Parks, John R. (A)
Chicago—Scherr, Eugene F. (M)

Kansas
Lawrence—Crane, Theodore H. (J)

Kentucky
Louisville—Moorman, Henry D. (A)

Michigan
Hancock—Tormala, James H. (J)
Whitehall—Longtin, Garth A. (R. C/S—J-M)

Minnesota
Chisholm—Rudstrom, Charles O. (M)
Minneapolis—Nelson, Marlowe A. (M)

Missouri
St. Louis—Augustson, Anders E. (C/S—J-M)

Nevada
Las Vegas—Hezzelwood, Lawrence L. (A)

New Mexico
Santa Rita—Wilmeth, Howard A. (R. C/S—S-M)

North Carolina
Gastonia—Robinson, Clyde H. (R. C/S—S-J)
Jefferson—Briggs, Marjorie A. (J)

Ohio
Cleveland—Laskevich, Stephen, Jr., (M)
Columbus—Brison, Robert J. (C/S—J-M)
Columbus—Langston, Benny (C/S—J-M)
Columbus—Mercier, Stanley M. (M)
Lakewood—Jones, William M. (M)
Shaker Heights—Yearley, Bernard C. (M)

Pennsylvania
Pittsburgh—Shoub, Earle P. (M)
Wilkes-Barre—Zimmerman, John J. (M)

South Dakota
Lead—Patterson, Alan J. (A)
Revillo—Bandt, Kermit M. (J)

Tennessee
Nashville—McFarlin, Carl, Jr. (M)

Utah
Magna—McLeod, Norman L. (A)

Wisconsin
Oshkosh—Zwickey, Wayne R., (J)

Alaska
Fairbanks—Butler, Maurice S. (R. C/S—S-M)

Argentina
Tres Cruces—Steele, Robert P. (El Aguilar, Prov. de Jujuy) (R. C/S—S-M)

Canada
Ontario, Toronto—Labow, Lawrence F. (M)
Ontario, Toronto—Morgan, George (A)

France
Paris—Destoumieux, Paul V. (M)
Paris—Thibault, Jacques F. (M)

Greece
Athens—Stavropodis, Jack D. (J)

Japan
Yawata City—Genzaburo, Havada (M)

Mexico
Chihuahua—Peyton, Francis K. (M)
Mexico D. F.—Guzmán Carreon, Luis (A)
Mexico D. F.—Reynoso, Manuel (M)

Peru
Cerro de Pasco—Chico, Raymundo J. (J)
Lima—Masters, Parke W. W. (A)

Sweden
Lindingo—Willners, Harry (C/S—A-M)

Appraisals
Assayers
Chemists
Construction
Consulting
Designing

Professional Services

Space limited to AIME members or to companies that have at least one member on their staffs. One inch, $40 per year; half inch, $25 payable in advance.

Geophysicists
Drilling
Management
Metallurgical
Reports
Valuations

ADAIR, BAILEY & VAN HORN
Minerals Consultants
Geology Mining Ore Dressing
Box 221, Murphy, N. C.

JAMES A. BARR
Consulting Engineer
Mt. Pleasant, Tennessee

BEHRE DOLBEAR & COMPANY
Consulting Mining Engineers and Geologists
11 Broadway New York 4, N. Y.

BLANDFORD C. BURGESS
Registered Professional Engineer
Mining Consultant
Monticello, Georgia

COWIN & COMPANY, INC.
Mining Engineers and Contractors
Shaft & Slope Sinking • Mine Development
Mine Plant Construction
1-18th Street SW,
Birmingham, Ala. Phone 56-5566

RENE ENGEL
Consulting Geologist
1222 Blair Avenue
South Pasadena, California
Telephone: ALbany 0912

GEORGE A. HOCH
Thin Section Technician
Standard and Oriented Sections
Unconsolidated Materials a Specialty
Dept. of Geology
Franklin & Marshall College, Lancaster Pa.

CARLTON D. HULIN
Mining Geology
26th Floor San Francisco 4
Shell Building California

PHILIP L. JONES
Consultant
Mineral Economics & Mineral Dressing
Heavy Media Specialist
405 Miners Bank Bldg. Joplin, Mo.
Tel. MAyfair 3-7161

C. P. KEEGEL
Mining and Metallurgical Engineer
Administration Appraisal
Specializing in Management and Consultation in Latin America
707 South 6th St., Las Vegas, Nevada
Telephone 571

KELLOGG KREBS
Mineral Dressing Consultant
564 Market St., San Francisco 4, Calif.

KIRK & COWIN
Consulting • Appraisals • Reports
1-18th Street SW,
Birmingham, Ala. Phone 56-5566

LEDOUX & COMPANY
Chemists Assayers Spectroscopists
SHIPPERS REPRESENTATIVES
Mine Examination Analyses
359 Alfred Ave. Teaneck, New Jersey

JOSEPH T. MATSON
CONSULTING MINING ENGINEER
Examinations—Appraisals
Operations
P. O. Box 170 Santa Fe, New Mexico

CLAYTON T. McNEIL, E. M.
Consulting Mining Engineer
822 Bank of America Bldg.
Tel. GArfield 1-2948
SAN FRANCISCO 4, CALIFORNIA

JUNE M. METCALFE
CONSULTING EDITOR-WRITER
Books. Brochures. Mining and Industrial Histories a Specialty.
88 Morningside Drive, N. Y. 27
Univ. 4-0200

ARNOLD H. MILLER
Consulting Engineer
Mine, Mill and Industrial Investigations
Improvement Design and Recommendations
Cable: "ALMIL" Tel. Cortlandt 7-0635
120 Broadway New York 5, N.Y.

RODGERS PEALE
Consulting Mining Geologist
315 Montgomery St.
San Francisco 4, Calif.

CHESTER M. F. PETERS
Mining Geology
Evaluations, exploration
and development programs
Colorado Plateau and adjacent areas
930 E. 3rd. South Salt Lake City, Utah

AMEDEE A. PEUGNET
CONSULTING MINING ENGINEER
Telephone MAIN 1-1431
705 Chestnut St. St. Louis 1, Mo.

LUCIUS PITKIN, INC.
Mineralogists
Assayers—Chemists—Spectroscopists
Shippers' Representatives
PITKIN BLDG., 47 FULTON ST., NEW YORK
Cable Address: Niktip

WILLIAM HELD PRATT
Geologist
Engineering Geology—Mining Geology
418 39th Ave. San Francisco 21, Calif.

MILNOR ROBERTS *Consulting Mining Engineer*
The Pacific Northwest,
British Columbia and Alaska
4501 15th Ave., N.E. Seattle, Wash.

WILLIAM J. SHEDWICK, JR.
Mine and Geologic Reports
Mexico and Latin America
New Jersey License 2744-a
Reforma 20-302 Mexico 1, D.F.

CLOYD M. SMITH
Mining Engineer
Mine Examinations
Ventilation Surveys
Munsey Building Washington 4, D.C.

SPANSKI AND WILLIAMSON
Geologists — Engineers
Groundwater Exploration
Engineering and Geological
Investigations
P.O. Box 151 Springfield, Ill.

H. W. STRALEY
Geology Geophysics
Box 68, Princeton, West Va.
1635 West Wesley Rd., NW, Atlanta, Ga.
CHerokee 6145

GODFREY B. WALKER
Metallurgical Consultant
Mineral Dressing & Extractive
Metallurgy
Heavy Media a Specialty
27 Lockwood Drive Old Greenwich, Conn.

O. W. WALVOORD CO.
Mill-Design and Construction
401 High St. Denver 3, Colo.

CLIFFORD R. WILFLEY
Consulting Mining Engineer
2233 Grape St. Denver 7, Colorado

HARRY J. WOLF
Mining and Consulting Engineer
Examinations—Valuations—Management
One Park Place, New York 7, N.Y.
Cable: MINEWOLF Tel: Rector 2-5307

ALFORD, MORROW & ASSOCIATES
CONSULTING ENGINEERS
Coal Mine Operation, Preparation
Prospecting and Development
Property Valuation
Oliver Bldg. Pittsburgh 22, Pa.

ALLEN & GARCIA COMPANY
42 Years' Service to the Coal and Salt Industries as Consultants, Constructing Engineers and Managers
Authoritative Reports and Appraisals
332 S. MICHIGAN AVE., CHICAGO
120 WALL ST., NEW YORK CITY

B. B. R. DRILLING CO.
National Road West
St. Clairsville, Ohio
Diamond Core Drilling Contractors
Mineral Cores Guaranteed
Foundation Testing

CENTENNIAL DEVELOPMENT CO., Inc.
Eureka, Utah
Tel. 172
Consulting Mining Engineers and Contractors
Shaft Sinking — Tunnel Driving
Mine Development
H. B. Spencer James Quigley

EAVENSON, AUCHMUTY & SUMMERS
MINING ENGINEERS
Mine Operation Consultants
Coal Property Valuations
2720 Koppers Bldg. Pittsburgh 19, Pa.

ENGINEERS ASSOCIATES, INC.
GRAND JUNCTION, COLORADO
Original Uranium Consultants
CHARLES W. YETTER • REGISTERED PROFESSIONAL ENGINEER
P.O. BOX 118 411½ MAIN ST PHONE 2499

FAIRCHILD AERIAL SURVEYS, INC.
Airborne Magetometer & Gradiometer Surveys, Topographic Mapping, Aerial Photography, and Photographic Mosaics for Mining Exploration.
224 E. 11th St. Los Angeles
30 Rockefeller Plaza New York

FETTERMAN ENGINEERING CO.
Civil & Mining Engineers
Consultants
Coal Mining—Property Valuations
Domestic & Foreign Examinations, Reports
Prospecting, Surveying, Mapping
Mine and Plant Layouts
Bank & Trust Building Johnstown, Pa.

Geo-Research
Geology Geophysics Mineralogy
Consultants
A Division of the
Institute of Industrial Research
SYRACUSE 10, N. Y. PHONE: 4-6454

ABBOT A. HANKS, Inc.
ASSAYERS-CHEMISTS
Shippers Representatives
624 Sacramento Street
SAN FRANCISCO

DIAMOND CORE DRILLING BY CONTRACT
and world's largest manufacturer
Core and grout hole drilling in coal, metal, and non-metallic deposits, both surface and underground.
JOY MANUFACTURING CO.
Contract Core Drill Division
Michigan City, Indiana

E. J. LONGYEAR COMPANY
Consulting Mining Engineers and Geologists
Contract Core Drilling
Diamond Core Drills and Supplies
Foshay Tower Minneapolis 2, Minn.

ROBERT S. MAYO
Civil Engineer Lancaster, Pa.
Specializing in Concrete Lining of Tunnels. Haulageways and Shafts. Special Equipment for Subaqueous Construction.

R. S. MC CLINTOCK DIAMOND DRILL CO.
Spokane, Wash. — Globe, Ariz.
Diamond Core Drill Contractors
Manufacturer of Diamond Bits and Drilling Accessories

JOHN F. MEISSNER ENGINEERS, INC.
Consulting Engineers
Conveyor Systems Storage Methods
Crushing Plants Ship Loading Docks
Materials Handling and Processing Plants
308 W. Washington St. Chicago 6, Ill.

DIAMOND CORE DRILLING CONTRACTORS
Testing Mineral Deposits
Foundation Borings
MOTT CORE DRILLING CO.
Huntington, W. Va.

PENNSYLVANIA DRILLING COMPANY
PITTSBURGH 20, PA.
DRILLING CONTRACTORS and MANUFACTURERS
We prospect coal and mineral land anywhere in North and South America. Core borings for foundation testing; dams, bridges, buildings, etc.

PRODUCTION AND MANAGEMENT SPECIALIST
ROGER V. PIERCE
Underground Mining Methods, Cost Cutting Surveys—Production Analysis —Mine Mechanization—Mine Management.
808 Newhouse Bldg. Phone 33975
Salt Lake City 4, Utah

PIERCE MANAGEMENT, INC.
MINING ENGINEERS
A Background of 27 years of Design, Consulting and Management Service to Coal and Mineral industries in 28 States and 18 Foreign Countries.
Scranton Electric Bldg., Scranton 3, Pa.
1025 Connecticut Ave., N. W.
Washington 6, D. C.

RESEARCH, INC.
Exploration Research and Service for the Mineral Industries
Geology Geochemistry Geophysics
Trace element analysis of soil and rock samples
1511 Levee Street
Dallas 7, Texas Phone Riverside 3395

M. G. SMERCHANSKI
Consulting Mining Geologist
Registered Professional Engineer
Examinations, Geological Surveys & Development
411 Childs Bldg. Winnipeg, Manitoba
Phone: 926323

SPRAGUE & HENWOOD, Inc.
SCRANTON 3, PA.
Diamond Drill Contractors and Manufacturers
Core borings for testing mineral deposits in any part of the world.

H. L. TALBOT
Consulting Metallurgical Engineer
Extraction and Refining of Base Metals
Specializing in Cobalt and Copper
Room 331, 84 State Street
Boston 9, Mass.

PAUL WEIR COMPANY
Mining Engineers and Geologists
Consultants and Managers
Design and Construction
20 No. Wacker Drive Chicago 6, Ill.

J. W. WOOMER & ASSOCIATES
Consulting Mining Engineers
Modern Mining Systems and Designs
Foreign and Domestic Mining Reports
Union Trust Bldg., Pittsburgh, Pa.
National Bank Bldg., Wheeling, W. Va.

WORLD MINING CONSULTANTS, INC.
Consulting Mining Engineers and Geologists
220 Broadway, New York 38, N. Y.
Worth 2-2934

Coming Events

Jan. 12, AIME, Connecticut Local Section, Bridgeport, Conn.

Jan. 13, AIME, Cleveland Section, annual dinner meeting, 6:30 pm, Manger (Allerton) Hotel, Cleveland.

Jan. 17-18, National Agricultural Limestone Institute Inc., 10th annual convention, Hotel Statler, Washington, D. C. Executive committee, January 15; board meeting, January 16.

Jan. 31-Feb. 2, Sixth Annual Southeastern Instrumentation Symposium, University of Florida, Gainesville.

Feb. 3-5, Colorado Mining Assn., annual meeting, Denver

Feb. 10, AIME, Cleveland Local Section, American Room, Manger Hotel, Cleveland.

Feb. 14-17, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.

Feb. 21-24, American Concrete Institute, 51st annual convention, Hotel Schroeder, Milwaukee.

Mar. 9, AIME, Connecticut Local Section, Bridgeport, Conn.

Mar. 10, AIME, Cleveland Local Section, American Room, Manger Hotel, Cleveland.

Mar. 16, AIME, Connecticut Local Section, annual meeting, Statler Hotel, Hartford, Conn.

Mar. 20-23, American Institute of Chemical Engineers, Kentucky Hotel, Louisville.

Mar. 28-Apr. 1, Ninth Western Metal Exposition, Pan-Pacific Auditorium, and **Ninth Western Metal Congress,** Ambassador Hotel, Los Angeles.

Apr. 13, Material Handling Institute, spring meeting 10:00 am, Drake Hotel, Chicago.

Apr. 14, AIME, Cleveland Section, joint meeting with American Ceramic Society, NACA Laboratories, Cleveland Hopkins Airport.

Apr. 18-19, Third National Air Pollution Symposium, Pasadena, Calif.

Apr. 18-20, AIME, Blast Furnace, Coke Oven and Raw Materials, and National Open Hearth Steel Conferences, Bellevue-Stratford Hotel, Philadelphia.

Apr. 18-22, American Society of Mechanical Engineers, Diamond Jubilee spring meeting, Lord Baltimore Hotel, Baltimore.

Apr. 19-21, Canadian Institute of Mining and Metallurgy, annual meeting, Royal York Hotel, Toronto.

Apr. 28-30, AIME, Pacific Northwest Conference, Spokane.

May 16-19, American Mining Congress, 1955 Coal Show, Cleveland.

June 26-July 1, American Society for Testing Materials, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Sept. 19-22, AIME, Industrial Minerals Div., fall meeting, Asheville, N. C.

Oct. 6-8, AIME, Utah Section, Rocky Mountain Industrial Minerals Conference, Salt Lake City.

Oct. 6-8, AIME, Minerals Beneficiation Div., fall meeting, Salt Lake City.

Oct. 9-13, American Mining Congress, metal-mining meeting, Las Vegas, Nev.

Oct. 19-20, ASME, AIME, fuels conference, Neil House, Columbus, Ohio.

Nov 13-18, American Society of Mechanical Engineers, Diamond Jubilee annual meeting, Congress, Hilton, and Blackstone Hotels, Chicago.

Advertisers' Index

Allis-Chalmers Mfg. Co., General Machinery Div. — 9
Compton Advertising, Inc.

Allis-Chalmers Mfg. Co., Tractor Div. — *
Bert S. Gittins Adv.

American Cyanamid Co. — *
James J. McMahon, Inc.

Anaconda Copper Mining Co. — *
Kenyon & Eckhardt, Inc.

Aros Electric, Inc. — *

Brunner & Lay, Inc. — *
Norman P. Hewitt Adv.

Bucyrus-Erie Co. — *
Bert S. Gittins Adv.

Cape Ann Anchor & Forge Co. — 90

Caterpillar Tractor Co. — 24
N. W. Ayer & Son, Inc.

Chain Belt Co. — *
The Buchen Co.

Cleveland Rock Drill Div. — *
Hoffman & York, Inc.

Colorado Fuel & Iron Corp. — 4
Doyle, Kitchen & McCormick, Inc.

Copco — *
J. J. Gibbons, Ltd.

Deister Concentrator Co. — 2
Louis B. Wade, Inc.

DeLong Corp. — *
The McCarty Co., Inc.

Denver Equipment Co. — *
Bill Bonsib Adv.

Detroit Diesel Engine Div. — *
Kudner Agency, Inc.

Diamond Products, Inc. — *
Ritchie & Sattler, Inc.

Dorr-Oliver, Inc. — 6, 7
Sutherland-Abbott Adv.

Dow Chemical Co., The — 10
MacManus, John & Adams, Inc.

Dravo Corp. — *
Ketchum, MacLeod & Grove, Inc.

Dwight-Lloyd, Inc. — 92
Spooner & Kriegel

Eimco Corp., The — 16
Matsie Co.

Fairchild Aerial Surveys, Inc. — *
Clyde D. Graham Adv.

Gardner-Denver Co. — 5
The Buchen Co.

Hardinge Co., Inc. — 81
The W. H. Long Co.

Hercules Powder Co. (Explosives) — *
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) — *
Fuller & Smith & Ross, Inc.

Hewitt-Robins, Inc. — *
Fuller & Smith & Ross, Inc.

Heyl & Patterson, Inc. — *
Dan A. Sullivan Adv.

Houston Technical Laboratories — Third Cover
Don L. Baxter, Inc.

Ingersoll-Rand Co. — *
Rickard & Co.

International Nickel Co., Inc. — 12
Marschalk & Pratt Co.

Jeffrey Mfg. Co. — *
Byer and Bowman

Joy Mfg. Co. — 93
Walker & Downing

Metal Carbides Corp. — 82
Meek and Thomas, Inc.

Mine & Smelter Supply Co. — 11
Walter L. Schump, Advertising

Mine Safety Appliances Co. — Fourth Cover
Ketchum, MacLeod & Grove, Inc.

Nordberg Mfg. Co. — 17
Russell T. Gray, Inc.

Northern Blower Co. — *
Carr Liggett Adv.

Phelps Dodge Refining Co. — 80
The House of J. Hayden Twiss

Precision Radiation Instruments, Inc. — 2
The McCarty Co.

Sauerman Bros., Inc. — *
Symonds, MacKenzie & Co.

Sheffield Steel Co. — 22
R. J. Potts-Calkins & Holden Adv.

Sintering Machinery Corp. — 92
Spooner & Kriegel

Sprague & Henwood, Inc. — *
Frederick B. Garrahan Adv.

Stearns-Roger Mfg. Co. — 86
Gray & Co., Inc.

Stephens-Adamson Mfg. Co. — *
Glenn, Jordan, Stoetzel Inc.

Stratex Instrument Co. — 90
Frank Bull & Co.

Texas Gulf Sulphur Co. — *
Sanger-Funnell, Inc.

Traylor Engrg. & Mfg. Co. — 3
The William B. Kamp Co.

Tyler Co., W. S. — 78

United States Rubber Co. — 14
Fletcher D. Richards, Inc.

Western Machinery Co. — *
Boland Associates

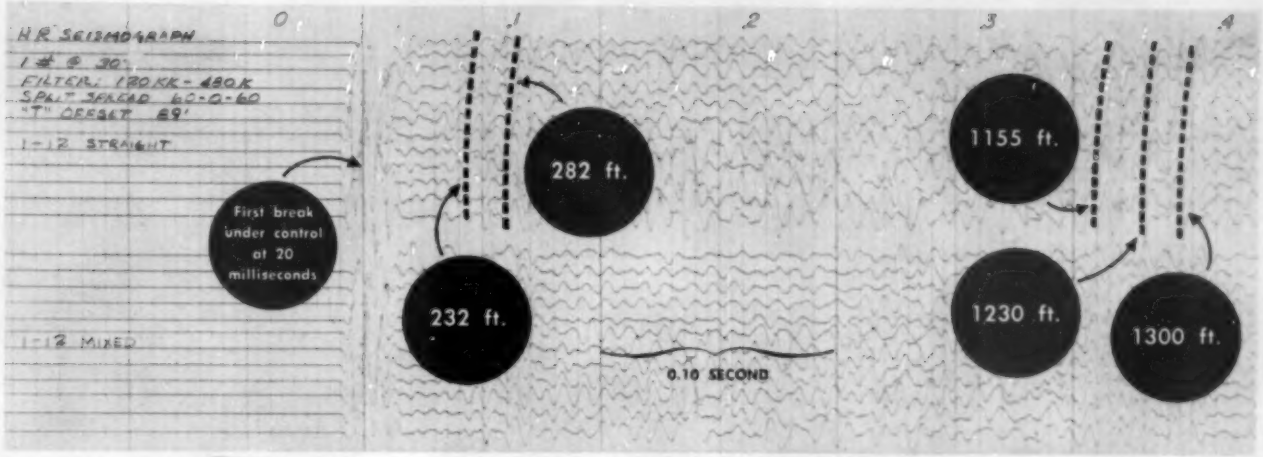
Westinghouse Air Brake Co. — *
Hoffman & York, Inc.

Wilfley & Sons, Inc., A. R. — Second Cover
Ed M. Hunter & Co.

Wilmot Engineering Co. — 91
Wilbur A. Myers Adv.

Yuba Mfg. Co. — 88
Geo. C. McNutt Adv.

* Previous Issues



High Resolution

here's a new record for near-surface seismic data

If you're plagued with the problem of obtaining accurate near-surface seismic data, look carefully at the record illustrated here. With first breaks under control in 20 milliseconds, a reliable reflection was obtained at a depth of 232 feet. This record is typical of the results obtained by the new Houston Technical Laboratories High Resolution Seismic System. A major development in geophysical prospecting, the HTL portable HR System now makes possible reliable reflection surveys over a depth range of 100-2500 feet. It is especially designed for use in petroleum exploration, mining, ground water location, and civil engineering where shallow seismic information is vital.

WRITE for Technical Bulletin No. S-303 for additional information about how you can now make shallow seismic surveys.

use the HTL portable HR seismic system to determine:

- thickness of gravels and other unconsolidated materials;
- depth and extent of buried channels;
- location and delineation of shallow mineral beds or seams, dikes, pinchouts, lenses and similar features.

HTL

HOUSTON TECHNICAL LABORATORIES

A SUBSIDIARY OF TEXAS INSTRUMENTS INCORPORATED

2424 BRANARD • HOUSTON 6, TEXAS, U.S.A. • CABLE: HOULAB

Here's why the Edison R-4 Double Filament Bulb saves Productive Man-hours— promotes greater underground safety

With the Edison R-4 double filament bulb, a burned-out filament doesn't mean lost time for the miner or a short crew for the foreman. A turn of the switch transfers the power of the unfailing Edison battery to the second filament—restores *continued, brilliant illumination*. There is only one bulb, located in the center of the headpiece, which gives the advantage of maximum reflector area.

This reserve protection saves hundreds of man-hours every year, adds an extra margin of safety. Write for full details.

BURN-OUT doesn't mean BLACKOUT

MSA

SAFETY EQUIPMENT HEADQUARTERS

MINE SAFETY APPLIANCES COMPANY

201 North Braddock Avenue, Pittsburgh 8, Pa.

At Your Service: 77 Branch Offices in the United States and Mexico

MINE SAFETY APPLIANCES CO. OF CANADA, LTD.

Toronto, Montreal, Calgary, Edmonton, Winnipeg, Vancouver, Sydney, N.S.

When you have a safety problem, M.S.A. is at your service . . . our job is to help you